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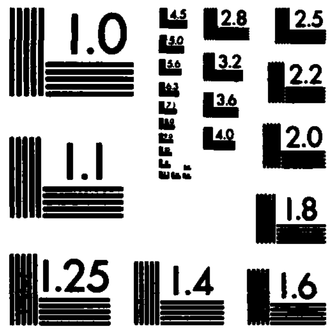

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SCANNING PHOTOELECTRIC DEVICES OF SEARCH AND TRACKING

by

G. P. Katys

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By: G. P. Katys

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U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

GRAPHICS DISCLAIMER

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SCANNING PHOTOELECTRIC DEVICES OF SEARCH AND TRACKING.

G. P. Katys.

Page 2.

This work is the third in the cycle of the books of the author the "Scanning systems". The book is dedicated to the examination of the operating principles, characteristics and methods of calculation of the scanning systems, intended for the control of parametric fields.

In the book are examined the principles of the construction of different scanning systems, intended for the search and the tracking the chosen regions of parametric field. Are examined the paths of construction of scanning systems, optimum for the specific criteria, and are presented the methods of their calculation.

In the first section is presented the complex of the questions, which appear during creation and development of the search scanning devices/equipment of different operating principles: is given their classification, are given different methods of scanning fields, are investigated their fundamental characteristics; are presented the elements/cells of the theory of some classes of the search scanning devices/equipment.

In the subsequent sections is examined the series/row of

examples of scanning systems, intended for purposes of search and tracking, and are also examined some developments of the author, are given materials on their theoretical and experimental study and are examined their characteristics. For some systems are given the calculation procedures.

The book is intended for engineers and scientific coworkers, who are occupied by the automatic check of unsteady parametric fields.

Page 3.

Introduction.

This book is the third in the cycle of the work of the author the "Scanning systems". In the first book of this cycle [7] is given the classification of the scanning systems, are examined the principles of their construction, are given some elements/cells of theory and methods of calculation of such systems. In the second book are examined the scanning systems and the elements/cells of the automatic control of the fields of the velocities and expenditures/consumptions.

The purpose of this work are examination and the analysis of the principles of the construction of the existing scanning devices/equipment, the development/detection promising trends in development and optimum fields of their use/application, the

development of the series/row of the new principles of the construction of the scanning systems, the creation of the corresponding devices/equipment and the development of the methods of calculation of their elements/cells.

In the book primary attention is concentrated in the examination of the primary cells of the scanning devices/equipment, i.e., those elements/cells which realize strictly scanning. Questions of reproduction and analysis of image are presented in the preceding/previous work of the author [6, 7] and they here touch upon briefly.

In the first section are examined the elements/cells of the theory of the optimum construction of some types of the scanning systems, are given the results of experimental investigations and the methods of calculation of some versions of such systems. In the subsequent sections are presented the principles of the construction of the search and servo scanning devices/equipment, are examined both types of the scanning systems, intended for obtaining the information about the state of the parametric field: the devices/equipment, which realize electromechanical scanning of the complex of the sensors, arranged/located on the projection of the controllable/controlled/inspected field, and the devices/equipment, which realize scanning the image of parametric field with the aid of

the scanning beam. Are examined also versions of both types of devices/equipment, developed for different targets, are given their fundamental characteristics and some elements/cells of theory.

In the second section are presented the principles of the construction of the optical search scanning devices/equipment, in the third - principles of the construction of the optical followers.

In the book in essence are examined the most widely used at present scanning systems - system of passive scanning, i.e., system with the preestablished program of scanning. Are examined two types of such systems with the scanning beam: the systems, which realize control of the image of parametric field by progressive scanning of image with the aid of one sensing element and of the special optical or photoelectronic device/equipment, and system with certain number of sensing elements, distributed in the plane, to which is designed the controllable/controlled/inspected image of field.

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In the case of using the complex of sensing elements, located in image plane of the controllable/controlled/inspected field, the request of sensors is realized with the aid of different scanning devices/equipment.

In the book are investigated only optical systems; however, the basic principles of the construction of such systems can be partially propagated also to the systems of other operating principles (nonoptical). Scanning systems considered/examined here are subjected to analysis and comparison.

Systems with the scanning beam are applicable for the solution of problems;

1) control and the control of parametric fields in the thermal objects (for example, temperature fields in the furnaces, the special combustion chambers and other similar units);

2) control and direction of the continuous processes when parametric field and its characteristics change during the motion of material along its processing machines (for example, the control of continuous technological processes in the chemistry);

3) control and direction of the automatic assembly of machines and mechanisms in the complete absence of people when is supervised of the geometric relationships/ratios in the specific field of the events which are compared with the given ones according to the

program of assembly;

4) search and tracking the special objects;

5) navigation and attitude sensing.

The method of line-by-line resolution received wide acceptance during the analysis of parametric fields and it is applied in different areas of technology (television, phototelegraphy, and also the series/row of special regions). Similar scanning systems are subjected to the most in-depth theoretical and experimental study.

Questions of the automatic control of variable fields can be approximately divided into the following three groups:

1) the automatic control of nonstationary field for the purpose of the explanation of the general state of field and signaling on leaving of field from the assigned state;

2) the automatic control of variable field for the purpose of tracking the section of the field of the assigned level of the parameter;

3) the automatic control of the variable field, target of which

is orientation during the motion within the parametric field.

The necessity for the automatic control of variable fields arose in the technology recently; therefore this region little was developed.

In this book the author examined the general state of a question, are systematized the results, obtained by other authors, and are presented the results of their own works in this region. Are examined the principles of the construction of the scanning systems, and are also developed the methods of calculation of such systems.

Work is done under academician B. N. Petrov's management/manual.

Section I.

SCANNING OF VARIABLE FIELDS.

In this section are examined general/common/total questions of designation/purpose, principles of construction and theory of the systems, which realize automatic control of fields with the aid of the scanning beam.

Chapter 1.

PURPOSE OF THE SCANNING SYSTEMS.

Recently in the practice of the automatic check arose many problems, which require fundamentally new approach both in the theoretical examination of the problems of control and in their equipment solution. One of such problems is the automatic check of unsteady parametric fields. With the execution of this control it is impossible to judge the state of field by the value of the parameter at its any point and because of this it is necessary to analyze the necessary parameter at all (or in many) points of field.

Continuous survey and analysis of parametric field is necessary also when in the separate places of object the parameter can exceed critical value, as a result of which the object can malfunction.

In all these cases the continuous survey of field (scanning) is the almost only means of control, since the interesting us value of the parameter is distributed in the field somehow randomly (i.e., we do not know its precise location and sometimes we only know the probabilities of its determination at the points of field or probability of its appearance in the course of time at these points).

The same type of problem they appear in different areas of new technology when, for example, in the space it is necessary to find any object.

Furthermore, it is necessary to note that the automatic check of parametric fields by itself is the powerful/thick means of the experimental experiment of the objects, which work in the nonstationary systems.

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From entire that stated above it is evident that questions of the control of parametric fields have high value. The problems, similar to the problems of the automatic check of fields, appear also in other areas of science and technology - in the radar, television, theory of search (occupying by the search for points or zones in the space), etc.

For the control of parametric fields it is possible to apply the diverse scanning systems, which are distinguished between themselves by the methods of scanning, placed as their basis. The actually fulfilled operations/processes all systems it is possible to

subdivide into:

those accomplishing the passive development/scanning, realized according to the predetermined constant/invariable program;

accomplishing active development/scanning fields whose program changes during the process of scanning in the dependence on the concrete/specific/actual picture of field.

Both active and passive systems they can examine/scan field either continuously (process of survey continues on all points of field without the interruption), or it is discrete, with the interruption/discontinuity (in the time or in the space).

In the work are examined in essence the systems, which realize passive and continuous scanning of field.

The section of plane field can be completely covered with the most arbitrary trajectories of scanning, but in the technology the widest use received line-by-line and circular sweeps, since it is possible to carry out them with the aid of the sufficiently simple devices/equipment.

The execution of the scanning system can be very diverse

depending on what parameter of field it is monitored and what type of scanning image is optimal in this case. The signal, obtained from the scanning device/equipment, after the appropriate amplification enters the scaling circuit in which taking into account the method of automatic control used is formed/shaped the electrical signal, proportional to the value of the parameter of points of the field, scanned at a given moment/torque. Obtained thus electrical signal in the dependence on the designation/purpose of the scanning system can be given either to the recorder or to the appropriate actuating mechanism.

The type of scanning, and also the rate of scanning of object are determined by stated problem and dynamic properties of object.

Depending on the form of the controllable/controlled/inspected object, its dynamic properties and relief of parametric field are selected the type of the scanning device/equipment (optical-mechanical or photoelectronic) and the form of scanning/sweep (axisymmetric or centrally symmetrical).

Page 7.

From the analysis of the operating principles of the developed at present search scanning systems it is possible to make some

conclusions about possible trends in their development. The first direction it is possible to consider use/application for purposes of scanning usual optics, aimed at one point of object and established/installed on special mechanism. In this case the latter changes the three-dimensional/space location of the optical axis of system in such a way that is conducted scanning object along the required trajectory. Main disadvantage in such devices/equipment is a small allowable speed of scanning, since the spatial motion completes entire device/equipment, which has a comparatively large mass.

The second direction compose the scanning systems, in which scanning/sweep of image is realized by means of the optical-mechanical device/equipment, and the third - systems with the photoelectronic scanning/sweep of image.

The optical-mechanical scanning can be made by two methods. The first consists in the fact that during the scanning the axis of the luminous flux, which goes from the object, does not change its attitude and the alternating coverage of path for the luminous flux is conducted in such a way that to the photocell at the given moment/torque would be projected/designed only one image point (according to this principle works the well-known disk of Nipkow).

The second method is reduced to the fact that on the path of the

luminous flux, which goes from the object, is established the optical element/cell (mirror or prism), which guides flow to the opaque screen after opening/aperture of which is established/installed the photocell. Mirror or prism changes its attitude, continuously changing thereby the position of the axis of the luminous flux. Thus are achieved the corresponding image drifts of field being scanned relative to motionless photocell, which creates the required scanning/sweep of image.

For executing the line-by-line scanning of field to mirror can be attached two oscillatory motions relative to two mutually perpendicular axes. If frequency around one axis by an order is lower than the frequency relative to another axis and, furthermore, if the amplitudes of oscillations are identical (with the square raster) and have the required value, then will be realized the line-by-line scanning/sweep of image. Possibly also execution of in parallel-line scanning devices/equipment in the form rotating mirror drum whose faces have different inclination/slope toward the rotational axis.

For the spiral shift of the image of the scanned field relative to motionless sensing element are applied the optical systems, which consist of two prisms (or asymmetric lenses), which rotate with the different velocities.

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In the photoelectronic scanning devices/equipment scanning/sweep of image is realized, as a rule, by diverging the flow of photoelectrons by external magnetic fields.

Efficiency of the scanning systems can be evaluated according to different characteristics. Very important characteristic is its ability to detect object in the presence of noises. In this case the factor of the estimation of system is the relation signal - noise. In the systems appear the noises of two types: creating in the electronic circuits and with the mechanical vibrations; appearing as a result of the presence of the specific background on which is located the controllable/controlled/inspected zone or point. In the rationally designed systems the noises, which are created in the electronic circuits, with the mechanical vibrations, with the work of servo system must be brought to the minimum.

A separation of object and background can be carried out either by the use of a minimally narrow instantaneous field of the view of system or by the use/application of a modulation grid, established/installed in the focal plane of optical system. This grid modulates only signal from the object. From the optical system in this case it is required so that in the plane of grid it would image

of object, which has minimal sizes. Since any optical system has the limited resolution, the possibility of system to realize a selection according to image size against the background in the final analysis is limited to image quality or to resolution of optic/optics.

Depending on the series/row of the parameters, is selected the optimum region of the spectrum for the work of system, which causes the need of applying the optical materials with a good passing ability in this region of the spectrum. The properties of reflecting optic/optics do not depend on wavelength to this degree as in the refracting optic/optics. However, in many instances form and size/dimension of construction/design make it possible to create the best scanning system only under the condition of applying the refracting optic/optics. In this case in a number of cases of the systems, which consist of the lenses and the mirrors, they are the best type of optical systems. Energy losses due to the black spot at the entrance of mirror objective and great difficulties of producing the reflecting optical elements/cells of the required geometric form cause the need of using the refracting optic/optics.

The scanning systems it is possible to subdivide into two large classes:

1) the systems, which apply different types of scannings/sweeps

for the search and trackings;

2) system; the using bringing images of object it is direct to the optical axis of coordinator.

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The systems of the first class can work both with tracking and in the search mode, systems of the second class are utilized only for the tracking the object. Furthermore, use/application of scanning/sweep of the controllable/controlled/inspected field gives the possibility of its television reproduction, which can have vital importance for the series/row of special systems.

Recently considerable attention is paid to the development of the systems of navigation and autonomous systems of search and tracking with the aid of which it is possible to obtain information relative to the orientation of apparatuses or to reveal/detect the position of one or the other object in the space. In this case the systems of search and the trackings, which act in the optical range, receive increasing propagation because of the considerable successes in the region of developing the new radiation detectors, in which is considerably lowered the interference effect from the background. To this contributes also the development of the small cooling systems,

necessary for sensitization of receivers. Recently are also created the new refracting materials with the high coefficient of transmission and a small scattering, which makes it possible to create highly efficient optical systems.

The region of the spectrum, in which is arranged/located the maximum of the radiations/emissions of unit, it is determined by the absolute temperature of object. The higher it is, in the region of shorter wavelengths is arranged/located the maximum of radiation/emission. Object with the temperature approximately 300° has a maximum of the intensity of infrared radiation approximately/exemplarily on the wave $\lambda=5$ μ. At a temperature of object of 100° maximum approximately/exemplarily corresponds to wavelength 7.8 μ. The heated metallic parts of the engines have a maximum approximately/exemplarily with $\lambda=3.5$ μ. In this case it is necessary to note that the solar radiations reflected from the object have a maximum of the intensity of radiation/emission at the wavelength 0.4 μ.

The systems, which recover the energy, emitted by object, have advantages over the systems, which use reflection of energy from the object, as a result of the use of more intense sources and shorter wavelengths of the radiation/emission adopted, and also due to the absence of the problems, connected with the atmospheric refraction.

The angular resolution of system in the final analysis is determined by the ratio of the sizes/dimensions of the inlet of optic/optics (or the size/dimension of antennas) to the wavelength of radiation/emission. Therefore the systems, based on the use of smaller wavelengths, have high resolution with the smaller sizes/dimensions of the inlet of optic/optics (or antenna). These facts will make it possible to also increase relation signal - noise in the system. The shorter lengths of the there adopted radiation/emission give the possibility to decrease the receiving aperture and to at the same time throttle/taper the beam width of system.

An increase of the relation signal - noise in this case is obtained as a result of the decrease of the ill effect of background.

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Chapter 2.

SOME QUESTIONS OF THE THEORY OF SEARCH. (rational construction of the scanning systems).

By the term "field" we imply the totality of the points, which fill the part of the space, to each of which corresponds any value of

the parameter interesting us. On that, in which space is taken the field are distinguished the fields one-dimensional (to each point of line corresponds any value of the parameter), two-dimensional (point they are arranged/located on the plane) and three-dimensional (points fill volume).

By the quantity of parameters interesting us the fields are divided into one- and multiparametric ones. Subsequently here are examined two-dimensional one-parameter fields.

With the automatic control of parametric fields can be required the most varied information whose form is caused by nature of the processes, which create the controlled field, by stated problems and by the possibilities of the means of automatic control.

On the objects, which have unsteady parametric fields, scanning systems are utilized for:

1) the explanation of the generalized field index according to which is conducted the control;

2) search and the detection of points and zones of the specific value of the parameter;

3) tracking the displacements of points and zones;

4) the study of the relief of the field (by relief is understood the surface, formed by the values of the parameter at any point of field);

5) the study of laws governing the change in this relief, i.e., for the research of the dynamics of processes;

6) the detection of isoparametric lines for field and constructions on them of the common picture of field, etc.

It is obvious that for the execution by each of the enumerated problems optimally can be used different types of the trajectories which are not equivalent to each other. In this case the same trajectory, used under varied conditions, can be more or less effective.

Parametric fields depending on their statistical properties can be divided into the fields, in which the probability of the occurence of specific event at certain moment of time is identical at all points, and to the fields, which have the specific laws governing the probability of the occurence of one or the other events in different regions.

In view of the fact that the information about the state of flat/plane parametric field can appear in its different fields, fundamental importance acquires the determination of the optimum "detail" of the removal/output of information.

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The majority of the controllable/controlled/inspected parametric fields has not the arbitrary character of the distribution of the parameters when the formation of the parametric zones of the assigned level or their change can occur equally probably in all places of field, but clear laws governing the possible formation of parametric zones. In this case as a result of the physical laws, which act in the object, are specific regions of the fields, in which is most probable the formation of the zones of the dangerous values of the parameter.

We consider that from the preceding/previous statistic studies to us is known the probabilistic distribution of the given one the value of the parameter. If during the prolonged interval of time field is not changed, then it is possible to assign it by the graph/curve of probability density P(x).

Value P(x)dx - probability that at the points, which belong to interval Δx, the value of the parameter is equal to the given one. But if in the process of scanning field is changed, then for any point of it is assigned probability F(t) of the fact that for time t the value of the parameter at this point will achieve the assigned magnitude.

If are assigned the laws governing the probability of the formation of dangerous zones to the field, then the scanning system must have such trajectory of the survey of field, which will realize with the larger "detail" scanning those regions where the probability of the occurence of the dangerous values of parameter is highest, and with less "detail", - regions where this probability is small.

During the development of the systems of the automatic control of parametric fields the very important question, which characterizes the informational possibilities of system, is the realization of the conditions, which are determining optimum perception by the system of information about the state of field, which in a some manner is distributed by the controllable/controlled/inspected area of field. In this case depending on the problem, stated before the system of automatic control, can substantially change the criteria of the

optimality of scanning and, consequently, also the principles of the rational construction of the system of automatic control. In a number of cases can prove to be useful the study of analogous processes in the visual apparatus of living organisms during the examination of images.

It is necessary to note that with the aid of the existing at present scanning devices/equipment it is possible to fulfill the very diverse types of the centrally symmetrical trajectories of scanning. The latter depending on the form of components of motion can be divided into the series/row of the classes whose informational possibilities essentially are distinguished (Fig. 1).

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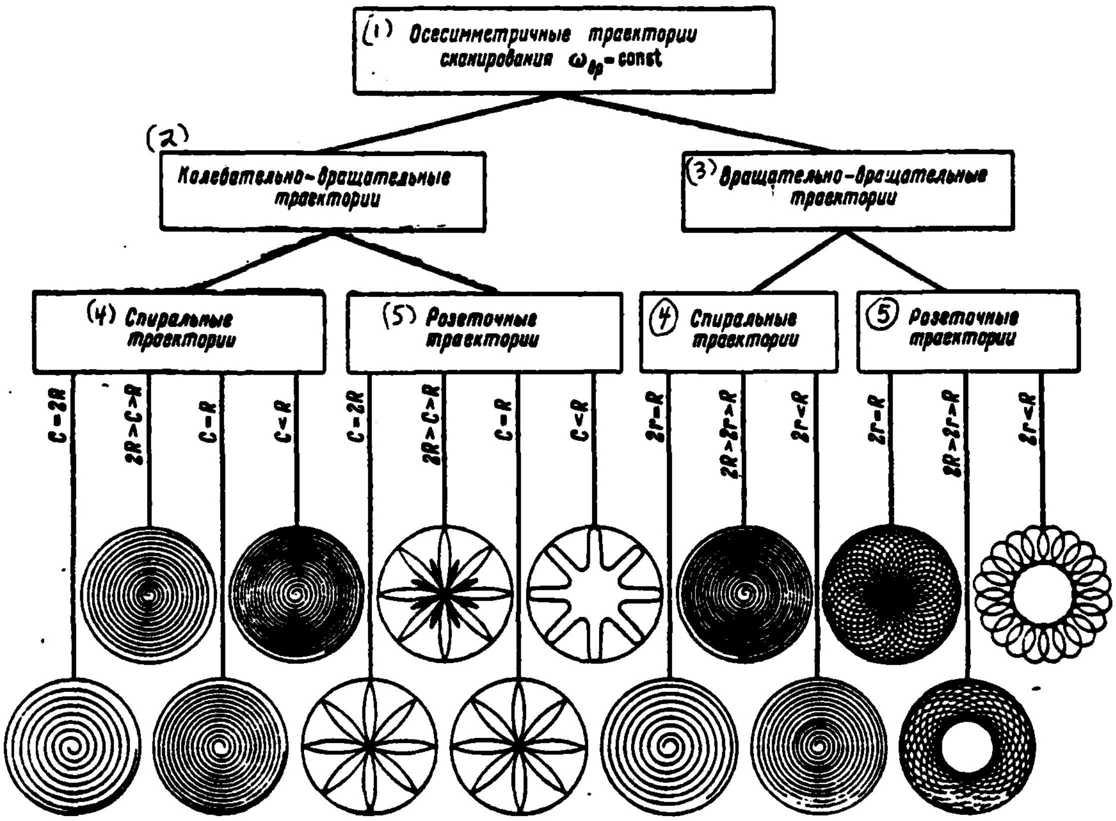

Fig. 1. Classification of trajectories of motion of scanning spot in different types of scanning devices/equipment.

Key: (1). Axisymmetric trajectories of scanning. (2). Vibrational-rotational trajectories. (3). Rotary-rotary trajectories. (4). Spiral trajectories. (5). Socket trajectories.

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Each of the trajectories enumerated in Fig. 1 of the motion of the scanning spot can be described in a specific manner from the point of view of the optimality of its use/application for the automatic check of the state of the field whose statistical properties are known.

Most frequently with the automatic control of the state of parametric fields appears the problem of detection in the field of the zone in which the value of the parameter interesting us exceeds the assigned level. This problem, for example, frequently appears during the control of the temperature fields when it is necessary to be convinced of the presence in the field of the zone whose temperature exceeds the specific level, and to also determine its coordinates. This problem can be solved, outcome from obtaining of the maximum of the overall probability of the detection of the unknown zone, via the selection of optimum for this case of the trajectory of scanning.

In order to rate/estimate the rationality of the use/application of one or the other trajectory of scanning or advantage of one trajectory over another, it is necessary to introduce the appropriate characteristics of trajectories.

Is examined below in essence search and detection of points and zones of the specific value of the parameter, assigned statistically. For the solution of this problem we will characterize centrally symmetrical trajectories with transit time of scanning the spots through any point field. Scanning field, spot can on several/somewhat times pass through one and the same point of field, the number of these passages n depending on the form of trajectory and diameter of the scanning spot.

The time during which is completed each separate passage by the scanning spot on the point of field, it is determined by the geometric dimensions of spot and by the velocity of its displacement:

$$t_i(x, y) = \int_{l_i} \frac{dS}{v_i(S)},$$

where l_i - trajectory phase within limits of which point (x, y) is located under the spot; $v_i(S)$ - velocity of the spot above the point (x, y) during this cycle of scanning.

The second important characteristic is the total time of the passage of the spot through this point after n passages:

$$t_{\text{сум}}(x, y) = \sum^{n} t_i(x, y) = \int_{l_1} \frac{dS}{v_1} + \int_{l_2} \frac{dS}{v_2} + \ldots$$
$$\ldots + \int_{l_i} \frac{dS}{v_i} + \ldots + \int_{l_n} \frac{dS}{v_n}.$$

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Consequently, so that it would be possible to judge the rationality of use/application of the specific type of trajectory for scanning of this field, it is necessary to know dependences Δt() for the series/row of those most widely used types of axisymmetric trajectories.

For determining the dependences $\Delta t(\rho)$ for the axisymmetric trajectories the author developed method of integral-temporary/time characteristics. Integral-temporary/time characteristic shows how change total intervals Δt of the time of scanning the point of round parametric field in the dependence on a radius ρ.

Complete time interval Δt is the sum of all values Δt_h, of those obtaining during scanning of the point of field with the displacement of spot over the adjacent trajectory phases. Dependence $\Delta t_{\text{ср}}(\varrho)$ for any type of socket trajectories (with c=R) can be sufficiently simply determined according to formula [6]

$$\Delta t_{\text{ср}}(\varrho) = \frac{ka^2}{4\varrho v_p(\varrho)}.$$

In the case of spiral trajectory we have [6]

$$\Delta t_{cp}(\varrho)=\frac{a^2}{8\varrho v_p(\varrho)}.$$

In the work of the author [5] are published the results of studying the characteristics of the trajectory of scanning indicated and are given graphs/curves $\Delta t=t(\rho;\ C)$ for different trajectories. Depending on the form of trajectory, selection of the period of scanning and diameter of the scanning spot these graphs/curves have very diverse character.

Is there examined the procedure of the determination of the optimum trajectory of scanning for the case, when centrally symmetrical parametric field is flat surface with the zero value of the parameter on which is arranged/located movable point (or zone) with the different from zero values of the parameter. We assume that the diameter of the unknown "point" (or zone) is lower than the diameter of the scanning spot. In this case is assigned the probability of location $p(\rho)$ of point in any place of axisymmetric parametric field. We assume that the velocity of displacement of the is considerably more than the velocity displacement of the unknown point scanning spots. Therefore during one period of scanning point can be considered motionless. We consider that we at disposal have the specific quantity of "search effort/force", which must be

distributed by the entire area of the scanned axially symmetric field so as to obtain the greatest overall probability of detection.

Work [6] gives and proved the sufficiently simple graphic method of the solution of this problem whose essence briefly is reduced to the following. On dependence $p(\rho)$ is constructed graph/curve $\ln p(\rho)$. Then is graphically filled with the value of total search effort/force Φ_Σ the volume, formed by rotation curve $\ln p(\rho)$ around axis $\ln p$.

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The obtained distribution of search efforts/forces is optimal in sense indicated above.

On the graph/curve of the optimum distribution of search efforts/forces $\varphi(\rho)$ it is possible to construct taking into account value γ graph/curve $\Delta t_n = f(\varrho)$ [6].

In order to select optimum trajectory, it is necessary to determine connection/communication between the volume of search efforts/forces Φ_Σ and the value of the period of scanning T:

$$T = \frac{1}{A}\Phi_\Sigma.$$

As shown in work [6], coefficient A for all types of

trajectories can be expressed by the formula

$$A = \frac{\pi a^2}{4};$$

where a - diameter of the scanning spot.

Thus, the volume of search effort/force, without depending on the type of trajectory, is determined by the value of full wave of scanning and by the area of the scanning spot. However, the type of trajectory determines the value of the maximum distance between the branches of trajectory and, consequently, also the value of the diameter of the scanning spot. In the assigned period T to different trajectories will correspond different number of lobes/lugs of socket or number of spiral arms and, which means, different diameters of the scanning spots.

To select the optimum trajectory of scanning is possible, on the basis of two different requirements: from the given ones period T of scanning and resolution of system (determined by the diameter of spot a); from the given ones of period T and maximum speed of scanning spot $v_{макс}$. In the first case from the group of those compared are eliminated all trajectories, in which $v_{макс}$ is more than permitted. Those remaining with identical T and a are compared with respect to the maximum conformity of the form of their integral-temporary/time characteristic $\Delta t(\rho)$ and dependence $\ln p(\rho)$.

In the second case, proceeding from the assigned values of period T, the maximally permitted rate of scanning $v_{макс}$ and form of function $\ln p(\rho)$, according to preliminary data, a number of trajectories (among which the best is then determined) is selected. The basis of the preliminary selection of the group of trajectories is the conformity of their characteristic $\Delta t(\rho)$ to the form of characteristic $\ln p(\rho)$ of the controllable/controlled/inspected field.

For the preliminarily selected group of trajectories and for T accepted and $v_{макс}$ we determine a precise geometry of each trajectory and diameters of the scanning spots. With this we check whether these trajectories satisfy the posed requirement on the resolution.

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For each type of trajectory we determine the value of complete search effort/force $\Phi_{\Sigma} = \frac{\pi a^2 T}{4}$ and with the aid of the graphic method examined we find its optimum distribution.

The optimum trajectory of scanning from the point of view of obtaining the greatest overall probability of target detection will be that which has the greatest filling of volume, obtained during the rotation of function $\ln p(\varrho)$ relative to the vertical axis ln p, taking into account the conformity of the dependences $\Delta t(\rho)$ and ln p(ρ). This finally can be determined by calculation in the latter/last stage of the comparison of the values of the total probability of detection [7].

Section II.

ELEMENTS OF SEARCH PHOTOELECTRIC AND OPTICAL-MECHANICAL DEVICES.

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Chapter 3.

PRINCIPLES OF THE CONSTRUCTION OF THE SEARCH SCANNING DEVICES.

The trajectories of scanning, which ensure the search for zone or point of field with the assigned properties, can be created with the aid of the scanning devices/equipment of different operating principles. Selective circuits it is possible to class as follows:

1) the optical-mechanical scanning devices/equipment, in scanning elements/cells of which is utilized reflecting optic/optics; they include:

a) the devices/equipment, which realize rotational-rotational trajectories of scanning (device/equipment with two asymmetrically established/installed mirrors, that rotate with different speeds; with the asymmetrically established/installed concave mirror, which accomplishes three-dimensional/space displacements/movements);

b) the devices/equipment, which realize vibrational-rotational trajectories of scanning (device/equipment with the flat/plane or

concave mirrors, which simultaneously accomplish oscillatory and rotary motion; in this case oscillatory motions to mirrors they can be given with the aid of different mechanisms - cam, three-dimensional/space and planetary);

c) the devices/equipment, which realize line-by-line trajectories of scanning (device/equipment with oscillating and simultaneously rotating mirrors; with different modifications of the mirror drum of Weiler; with the mirrors, which accomplish spatial motions with the aid of the cam drive).

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2) the optical-mechanical scanning devices/equipment, in scanning elements/cells of which is utilized the refracting optic/optics; they include:

a) the devices/equipment, which realize rotational-rotational trajectories of scanning (device/equipment with two optical wedges, which rotate with different angular velocities, with the asymmetrically established/installed lenses, which accomplish complicated spatial motions);

b) the devices/equipment, which realize vibrational-rotational

trajectories of the scanning (device/equipment with the polyhedral/multifaceted prism, which accomplishes rotation relative to two mutually perpendicular axes one of which it is the centerline of prism);

c) the devices/equipment, which realize line-by-line trajectories of the scanning (device/equipment with two polyhedral/multifaceted prisms, which accomplish rotation with different speeds relative to its axes which they are arranged/located at the right angle; with the set of the lenses, placed on the different height/altitude in the rotating mount/mandrel);

3) shielding scanners (in which with the aid of the movable screens with the openings/apertures to sensing element consecutively/serially are supplied the radiations/emissions from different sections of image);

4) the photoelectric scanning devices/equipment; to them relate:

a) different types of the contemporary camera tubes,

b) the photoelectronic scanning devices/equipment, which form difference signals of movable images,

c) the scanning devices/equipment of the type of photoelectronic gates/shutters,

d) the electroluminophor scanning devices/equipment,

e) the scanning devices/equipment with the fiber optic/optics.

Let us examine in more detail the fundamental characteristics of the enumerated above scanning devices/equipment. Let us begin from the optical-mechanical devices/equipment, in scanning elements/cells of which is utilized reflecting optic/optics. Are at present developed the devices/equipment, which realize both circular and line-by-line trajectories. In the devices/equipment of the first group one scanning motion is the rotary motion of the scanning element/cell, and the second motion depending on the type of trajectory can be either the rotary or oscillatory motion of mirror. It is necessary to note that the construction of such systems can be carried out in two directions: in the first case each scanning motion is realized with the aid of separate mirror [8], which accomplishes simple rotary motion; in second case both those of component/term scanning motions are created by one mirror [9], which fulfills complicated three-dimensional/space displacements/movements.

The scanning devices/equipment, which realize

vibrational-rotational trajectories, as a rule, have one mirror, which accomplishes simultaneously oscillatory and rotary motion. In this case for imparting to mirror the oscillatory motion are utilized the converters of rotary motion into the oscillatory - different types of cam, three-dimensional/space and crank mechanisms.

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Among this group sufficient to successful ones it is possible to recognize the device/equipment, in which the mirror is given in the rotational-vibrational motion with the aid of the end cam gear the rotational axis of which coincides with the optical axis of system [10].

Line-by-line trajectories can be formed by the mirror scanning devices/equipment of two types: generating with the aid of two mirror systems those two mutually perpendicular scanning motions; those simultaneously realizing with the aid of one mirror two mutually perpendicular displacements/movements of the scanning spot.

The systems of the first group include the device/equipment, in which with the aid of the turned mirror is conducted the frame scan of the image of field, and with the aid of the series/row of the concave mirrors, arranged/located on the rotary disk, the line

scanning of frame [11].

To the systems of the second group can be referred different variations in the scanning mirror drum of Weiler, and also device/equipment with the three-dimensional/space displacement/movement of the scanning mirror.

Is recently developed the scanning device/equipment, which is further development of the drum of Weiler and which consists of the series/row of the concave mirrors, fastened/strengthened to rotating drum [12]. The centers of these mirrors are somewhat displaced, which creates the line scanning of image. Motionless sensitive element is located in the center of drum. The combined rotation of all mirrors creates frame scan. The device/equipment examined sufficiently simply is compact. The devices/equipment in which the scanning mirror completes three-dimensional/space displacements/movements, can be carried out with the use of different drive mechanisms. In the most developed devices/equipment of this group to mirror are given oscillatory motions around two mutually perpendicular axes with the aid of two cam gears [13].

Let us examine the scanning selective circuits, in scanning elements/cells of which is utilized the refracting optic/optics.

The devices/equipment of this group, which realize the rotational-rotational trajectories (see Fig. 1), can be carried out with the aid of two rotating optical wedges, and also by means of the asymmetrically established/installed lens systems, which accomplish three-dimensional/space displacements/movements.

Devices/equipment with two rotating optical wedges scan different image points due to the birefringence with the passage of the images through two wedges whose mutual location continuously is changed [14]. This is reached via the drive of optical wedges with different angular velocities.

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Rotational-vibrational trajectories can be realized by devices/equipment of this group in which a multifaceted prism completes simultaneous rotation around two mutually perpendicular axes, one of which is its axis, and the second - by optical axis of device/equipment [15]. The radiations/emissions of unit, which passed through this prism, are directed then to the diaphragm with the opening/aperture, after which is arranged/located the photocell. Such devices/equipment are sufficiently simple and compact.

The line-by-line trajectories of scanning can be carried out

with the aid of the devices/equipment with by two that rotating polyhedral/multifaceted prisms whose axes are arranged/located at right angle [16]. These prisms rotate with different numbers of revolutions, the rotation of one prism realizing a frame scan of image, and the rotation of another - line.

The line-by-line trajectories of scanning can be also realized with the aid of the set of the lenses, established/installed at the different height/altitude in the rotating mount/mandrel, moreover motionless photocell is arranged/located in its center. During the rotation of mount/mandrel to the specific angle each lens completes scanning along one row.

Separate class compose the devices/equipment in which the scanning is realized by displacement/movement before sensing element of the special screens through openings/apertures of which alternately are supplied the radiations/emissions from different sections of image. However, these systems have low sensitivity.

Let us examine the group of the photoelectric scanning devices/equipment. For the resolution of the image is developed the series/row of the extensively used camera tubes (iconoscopes, iconotrons, orthicons, vidicons, dissectors, etc.). In these tubes for signal shaping are utilized different photoelectric processes,

which determines difference in their characteristics and regions of optimum use/application.

The positive property of the photoelectric vacuum scanning devices/equipment are them high the sensitivity, resolution and dynamic properties. However, their some deficiencies/lacks are determined by the high complexity, the presence of the blocks/modules/units, which form the signals of the special form, supplied to the deflection systems, by high sensitivity to the vibration and impact loads.

Are developed the photoelectronic scanning devices/equipment, intended for executing the series/row of the special problems, connected with the functional conversion of image. Thus, for instance, on the basis of the photoelectronic scanning elements/cells are developed the devices/equipment, which form the difference signals of movable images [17]. Such devices/equipment find use for the series/row of areas of technology where it is necessary to obtain information about the dynamics of a change in the image.

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The same group includes the scanning devices/equipment of the type of the photoelectronic gates/shutters, in which the consecutive

access of image elements to the photomultiplier is realized with the aid of the valve effect of electron beam on special light-conducting material [18]. These devices/equipment, developed comparatively recently, have thus far low sensitivity and resolution.

Recently are developed also the vacuumless photoelectronic scanning devices/equipment, based on the use of a phenomenon of electroluminescence [19]. In them the scanning is realized by means of the alternating feed on the mutually perpendicular transparent electrodes of the electrical signals, which trigger different sections of electroluminophor screen. The scanning element/cell of such devices/equipment is sufficiently simple; however, its sensitivity and resolution are low. To the same group can be referred the scanning devices/equipment with the elements/cells of fiber optic/optics which recently receive increasing propagation. Their use makes it possible to create the complicated scanning systems on the basis of the simple switching and scanning photoelectronic devices/equipment with the circular paths of scanning.

The promising principles of the construction of the search scanning devices/equipment it is possible to consider such, which make it possible by simple means to create devices/equipment with the high dynamic properties (short time of one cycle of scanning), high by resolution and by sensitivity. Desirable also that the utilized

operating principle would be made it possible comparatively simply to convert/transfer from the search mode to the mode/conditions of tracking by the simple changeovers of the elements/cells of block diagram.

Of essential interest are the devices/equipment of a zonal-piece-by-piece scanning, in which the search occurs not as a result of the consecutive survey of all elements/cells of field, but as a result of scanning field. Such devices/equipment can be carried out two types:

1) with the preliminary zonal scanning in process of which is defined the zone in which is arranged/located the object, and by the subsequent piece-by-piece scanning of this zone for the purpose of the explanation of precise coordinates of object;

2) with the zonal scanning in two mutually perpendicular directions; in this case the controllable/controlled/inspected image it is divided/marked off into the series/row of mutually perpendicular strips - the rows which they are simultaneously scanned by the appropriate devices/equipment.

Both first and the second of the group of device/equipment make it possible to substantially decrease the time of search, moreover

the gain in the time, created by the devices/equipment of the second group, considerably more than created by the first. Such devices/equipment can be realized with the use of very diverse physical principles.

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If we examine the reasons enumerated above for the construction of the scanning devices/equipment from the point of view of the physical laws, placed as their basis, then it is possible to note the following. Almost equivalent positive properties possess the photoelectronic and electroluminophor scanning devices/equipment. They can be carried out approximately/exemplarily identical sensitivity, also, with the equally high dynamic properties. However, the resolution of the photoelectronic scanning devices/equipment is considerably higher than electroluminophor ones. The major advantage of electroluminescent devices/equipment - simplicity of the scanning element/cell, its resistance to vibration and to impact loads.

In spite of the contradictory readings/indications of different characteristics of the scanning devices/equipment examined, apparently, sufficiently promising it is possible to consider electroluminophor, with the fiber optic/optics, and also new class of the simple optical-mechanical devices/equipment for drive of which are utilized elastic elements/cells. These groups of devices/equipment are in detail examined below.

Chapter 4.

PHOTOELECTRIC DEVICES OF ZONAL-PIECE-BY-PIECE SCANNING.

In this chapter are examined the photoelectric devices/equipment of zonal-piece-by-piece scanning, developed on the basis of the electroluminescent locking elements/cells.

For the line-by-line analysis of image find use new, vacuumless photoelectric devices/equipment. Thus, for instance, for scanning/sweeping the image can be used the electroluminophor amplifier of light/world with appropriate scanner [19]. The light image of object is projected/designed in this case for the photoconductive layer of the amplifier of light/world, as a result of which on the surface layer appears the "relief of resistances". A difference in resistances at the isolated points leads to the brightness modulation of the brightness of electroluminophor screen. Image from the screen is projected/designed with objective for the photocell. Resolution of the image is achieved by the successive excitation of brightness at the isolated points of screen. For this both current-conducting electrodes of the amplifier of light/world are fulfilled in the form of separate, isolated/insulated from each other strips, moreover the strips of one electrode are perpendicular

to the strips of another electrode (Fig. 2). The supply of the amplifier of brightness is realized by voltage pulses. The duration of the feeding pulses is selected equal to the time of the commutation of one element/cell.

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Impulses/momenta/pulses are supplied to each following strip at the moment of the termination of impulse/momentum/pulse on preceding/previous, and, thus, on the turn are scanned all sections of screen. At each moment of time only on one element/cell of screen, arranged/located on the intersection of vertical and horizontal inserts, electrical field will be proportional to dual signal amplitude. During the appropriate selection of the parameters of device/equipment it is possible to attain such position that only in this element/cell the electric field will be more than the threshold of phosphorescent glow. By this is provided the successive brightness with different brightness of the points of screen, necessary for the resolution of the image and for the appearance of the corresponding signal on the photocell.

For the case of search in the controllable/controlled/inspected field of one object (when on the field it is arranged/located only one object) by the author, together with V. A. Strokov, in IAT is

developed search-follow device/equipment in which as the scanning element/cell is used the set of electroluminescent gates/shutters [21]. Principle of scanning utilized in this device/equipment was applied earlier for the consecutive line-by-line scanning of rectangular raster. Original in development considered/examined below is the use of a new procedure of zonal scanning, which makes it possible to substantially decrease the read-out time of information about the position of object in the controllable/controlled/inspected field in comparison with the case of consecutive line-by-line scanning.

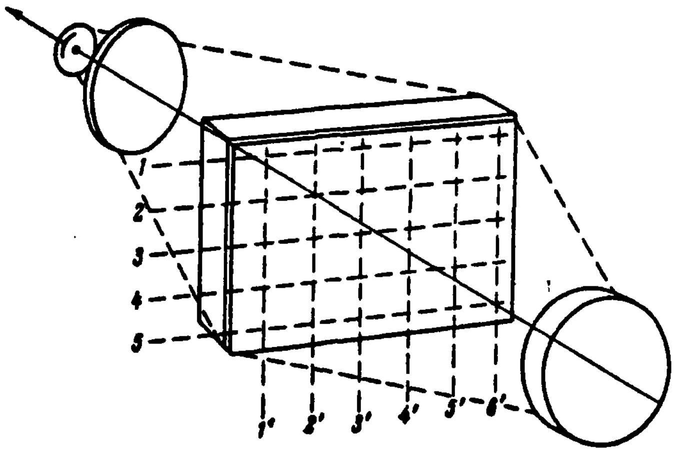

Fig. 2. Photoelectric scanning device/equipment with scanning/sweep of image with the aid of the electric fields on the intersected conductors.

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The operating principle of device/equipment is based on the use of an electroluminescent converter (Fig. 3), which consists of photoconductor 1 and electroluminophor 2. The photoconductor, which is the sprayed layer CdS, activated by Al, is connected in series with the thin layer (50 μ) of phosphor ZnS. The layers of phosphor and photoconductor from the outer sides come into contact with those conducting by transparent ones, plotted/applied to glass 6 and 7 electrodes [illegible] and 4, manufactured from oxide of tin. Between the phosphor and the photoresistor is arranged/located opaque conducting

interlayer 5 which is intended for preventing the reverse/inverse radiation effect of phosphor on the layer of photoconductor. In the device/equipment in question the analyzed section of field is projected/designed through optical system 8 for the photoconductive layer. If on photoconductor does not fall radiation/emission, its resistance is great and the large part of the stress/voltage, applied to the series-connected layers of photoconductor and electroluminophor, it falls on the photoconductor. The strength of field in the phosphor does not exceed the threshold level, necessary for the beginning of radiation/emission. When conductor is illuminated, its conductivity increases, and a voltage drop across phosphor becomes sufficient for the excitation of electroluminescence. In this case occurs the amplification of radiation/emission, determined by photoelectric amplification and nonlinear dependence of photo current and intensity of electroluminescent radiation/emission on the applied field. After this the intensive image is focused by optical system 9 to photocell 10. Scanning is conducted by the application/appendix of stress/voltage to the separate elements/cells of screen in the assigned sequence.

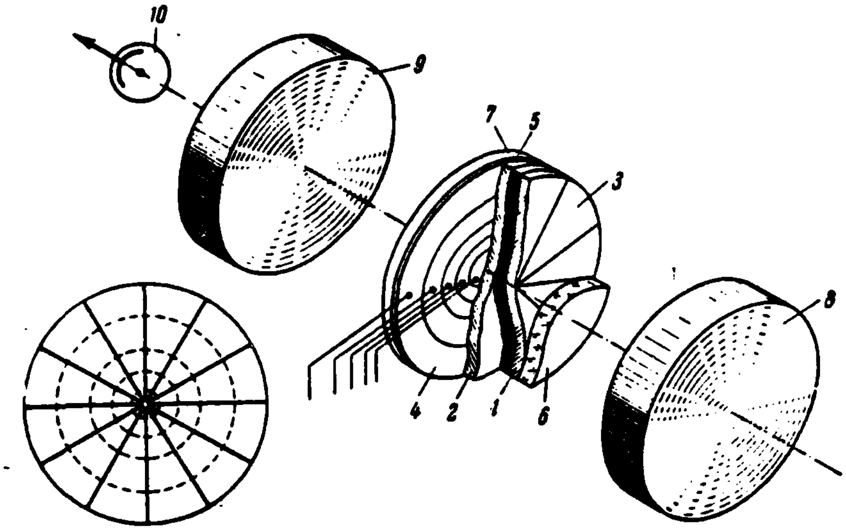

Fig. 3. Schematic diagram of the sensor of the electroluminescent search scanning device/equipment.

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For this electroluminophor it is placed between two systems of electrodes 3 and 4. These systems are two those isolated/insulated from each other of the group of the electrodes: the first is carried out in the form of concentric rings, the second - in the form of sectors. During the application of a potential difference to the circular and sector electrodes will be caused (depending on the location of the image of object) the brightness of electroluminophor on the element of area, which is determined by the overlap of the areas of the corresponding sectors and rings.

During the supplying to the sector and circular electrodes of heteropolar impulses/momenta/pulses (equal in magnitude) over the area of the overlap of the corresponding ring and sector is created the electric field whose intensity two times exceeds the intensity of the field, which is formed under the separate electrode. Phosphor is selected with the sharply pronounced threshold voltage of the excitation of electroluminescence, i.e., it has a sufficient intensity of the glow at the doubled intensity of electric field, and virtually it does not emit at the single intensity.

Scanning the elements/cells of photoelectric device/equipment is realized in the following order. First the voltage pulses are supplied simultaneously to all sector electrodes and consecutively/serially for each of the concentric rings (beginning from the internal). Thus is scanned entire/all sensitive area of sensor on the rings. The radiation/emission from the object, focused on any ring, during application to the electrodes of this ring of the voltage pulses causes phosphorescent glow. The latter is recorded by the photocell signal from which enters scaling circuit. After is determined the ring on which at the given instant is found the image of object, it is necessary to determine the sector of this ring in which is arranged/located the image of object. With the changeover of

the switching devices/equipment the voltage pulses are supplied to this ring and consecutively/serially to each sector element/cell. In this case consecutively/serially are scanned all elements/cells of ring and is revealed/detected the element/cell on which at the given moment/torque is arranged/located the image of object.

Thus, the process of position finding of the location of object is divided/marked off into two stages:

the zonal scanning on the rings for the purpose of the development/detection of ring, on which is arranged/located the image of object;

the piece-by-piece scanning of ring (during which is discovered the image of object) for the purpose of the determination of precise coordinates of the image of object.

This sequence of search makes it possible to substantially shorten the time, which requires to the target detection, since substantially is reduced the time interval, which requires for the search for object on all elements/cells of rings (in comparison with their complete consecutive survey).

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The radiation/emission of phosphor, which corresponds to this element/cell of screen, causes pulse signal on the photocell from parameters of which are determined the coordinates of object. After this to the indicator or the servodrive is supplied the corresponding error signal, which makes it possible either to fix/record object or to displace the optical axis of device/equipment in the direction to the object. Device/equipment is carried out in such a way that for a period of time when object is focused on the central circle, the error signal is not supplied, since in this case direction to the object and optical axis of device/equipment coincide. In this case occurs zonal scanning on the rings.

Scanning device/equipment examined above has a series/row of the positive qualities among which it is necessary to note the following. In the device/equipment is utilized the method of the automatic search, during which is realized at first zonal, then elementary scanning. The advantages, which appear as a result of this scanning, can be illustrated as follows. If we assume that the image of object is located on the fourth (external) ring (see Fig. 3), then for its detection it is necessary to expend on the search in the case of the beginning of scanning from the center the time, equal to $12\Delta t x 4 = 48\Delta t$ (where Δt - time of the commutation of one element/cell when each

ring it consists of twelve elements/cells). Utilizing the method examined, the detection time can be shortened to 16Δt (where 4Δt - scanning on four rings and 12Δt - piece-by-piece scanning of one ring). In this case occurs the considerable decrease of the time, which requires for the detection of the unknown zone of field.

Work [22] examines some questions, which relate to determining of the dimensions of sector and circular electrodes. On the basis of obtaining of identical sensitivity to the radiation/emission of unit with the entire area of photoconductor, it is possible to determine the sizes/dimensions of circular and sector electrodes. For this it is necessary that the elements/cells, formed by the overlap of the areas of circular and sector electrodes, would have equal resistance to the current, flowing during the application to them of stress/voltage. For this the areas of segmental elements/cells are made by equal ones.

The area of one sector is equal to $\pi D^2/4K_c$, where K_c — number of sectors, D - diameter of sensitive screen.

Then the area of the segments into which is divided/marked off entire sensitive screen,

$$S_{\text{сег}} = \frac{\pi(R^2 - r^2)}{K_c} = \frac{\pi D^2}{4K_c \cdot K_к},$$

where $K_к$ — number of rings; R and r - respectively outside and inside radii of the segment:

$$r = \sqrt{R^2 - \frac{\pi D^2}{4K_к}}.$$

r is an inside radius for each n ring and an external radius for n - 1st ring.

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Substituting initially R=D/2 and finding internal r for the n ring, it is possible to calculate internal r for n - 1st ring, taking for it external $R_{внешн} = r_{внутр}$ of the n ring, and so forth.

Thus entire/all sensitive area shares to the elements/cells equal by the area which must have equal dark resistance.

Concerning questions of the accuracy of device/equipment, it is necessary to mention about the errors, which are obtained with the isolation/liberation of the coordinates of the object of radiation/emission.

During the zonal scanning the error appears on a radius. If the image of object is located in the n ring (Fig. 4), then error with the reading from the middle of circular zone will comprise

$$H_{\text{м.п}} = \left(\frac{r_n - r_{n-1}}{2}\right) + 2\Delta d,$$

where r_n and r_{n-1} - external and inside radii of the n ring; d - diameter of the image of the object, arranged/located on the photoconductive layer; Δd - in the approximation/approach is the height/altitude of segment, the incidence/drop in the radiation/emission on the area of which (with its illumination) causes threshold current $I_{\Phi.\text{п}}$.

Value Δd is determined as follows. Knowing the material of photoconductor, it is possible to calculate leakage current $I_{\text{т}}$, which will flow/occur/last through the element/cell in the absence of radiation/emission from the object during application to the element/cell of a potential difference. Let us use the concept of threshold current $I_{\text{п}}$, which characterizes minimum illumination $E_{\text{п}}$, which creates an increase of the current through the photoconductor two times relative to the value of leakage current. Then the smallest area of photoconductor, which gives threshold current $I_{\Phi.\text{п}}$, comprises

$$S = \frac{I_{\Phi.\text{п}}}{KE_{\text{п}}},$$

where $I_{\Phi.\text{п}} = 2I_{\text{т}}$; K - integral sensitivity of the photoconductive layer.

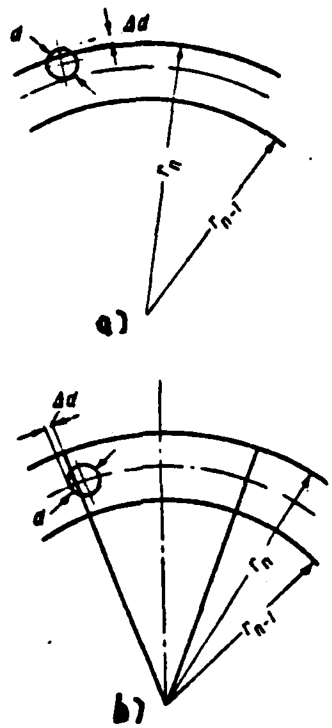

Fig. 4. Parameters of the sector (a) and circular (b) elements/cells of the scanning sensor.

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Value Δd is computed as the height/altitude of the segment of the circle with a diameter of d and with an area of S:

$$\Delta d = d \sin^2 \frac{360 \cdot S}{4\pi d}.$$

During the piece-by-piece scanning the error will appear as a result of the insensitivity along the length of arc (Fig. 5):

$$H_{c.п} = \frac{2\pi}{2K_c}\left(r_{n-1} + \frac{r_n - r_{n-1}}{2}\right) + 2\Delta d = \\ = \frac{\pi}{K_c}\left(\frac{r_n + r_{n-1}}{2}\right) + 2\Delta d.$$

In conclusion let us note that the device/equipment examined satisfies all requirements, presented to the contemporary devices/equipment of search and tracking. It is very compact, has light weight; an absence of the moving/driving parts, stability to the vibration and impact loads they increase the period of its service and provide sufficiently high reliability.

Chapter 5.

PHOTOELECTRIC DEVICES/~~EQUIPMENT~~ OF ZONAL SCANNING.

For the case of the search for one object (when on the controllable/controlled/inspected field it is located only the one object) is at present developed the series/row of the selective circuits, in which is realized zonal scanning.

Let us examine the selective circuit, intended for determining the coordinates of object [23]. Sensing element of this device/equipment is made in the form of grid from the interlaced photosensitive wires, moreover each of them is isolated/insulated from the rest and is arm of bridge (Fig. 5). The material of wires considerably changes its resistance in the dependence on the temperature. The scanning device/equipment consists of two identical sensing elements 1 and 2, of which one undergoes effect of radiation/emission, and another is darkened by screen and is intended for the compensation for the effect of ambient temperature (Fig. 6). The diameter of wires can be 50-100 μ. Each bridge element/cell consistently requests itself by the switching device/equipment, in this case the coordinates of object are determined by the parameters of those wire elements/cells, on which fell the radiations/emissions of unit.

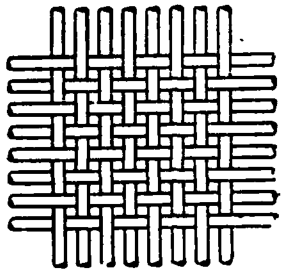

Fig. 5. Mesh search scanning device/equipment.

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The mesh sizes of sensing element must be selected by such that image size of object would be somewhat more than the size/dimension of one mesh.

The advantages of the examined device/equipment - in simplicity of diagram and in the possibility to conduct the search for object simultaneously along two coordinate axes, what considerably shortens the time of search, and deficiency/lack - in the low ones of resolution and sensitivity.

Is developed the series/row of the photoelectric devices/equipment of zonal scanning. Are developed the devices/equipment in which are used the paired sets of the figure photoresistors, to which are supplied the radiations/emissions from

the semitransparent mirrors, and devices/equipment with the fiber optic/optics. Let us examine consecutively/serially these devices/equipment.

In first type devices/equipment the image of the controllable/controlled/inspected field simultaneously is focused to two photocells, having this configuration photosensitive cells, which by their simultaneous and separate commutation is possible to rapidly determine the coordinates of object.

The operating principle of one of such devices/equipment is reduced to the following. With the aid of optics simultaneously on two photocells is focused the image of the unknown object (Fig. 7). As optics can be used objective 1 and semitransparent mirror 2 (or two separate objectives). Let us examine first the case when is monitored the field of circular shape; in this case both photocells have circular shape. Photocell 3 is made from the specific number of isolated/insulated sector photocells or photoresistors, while photocell 4 - from the series/row of circular photocells. Outputs from each photocell are given to the electromechanical or electronic switching device/equipment. During the search for object occurs the simultaneous commutation of the conclusions/outputs of sector and circular photocells.

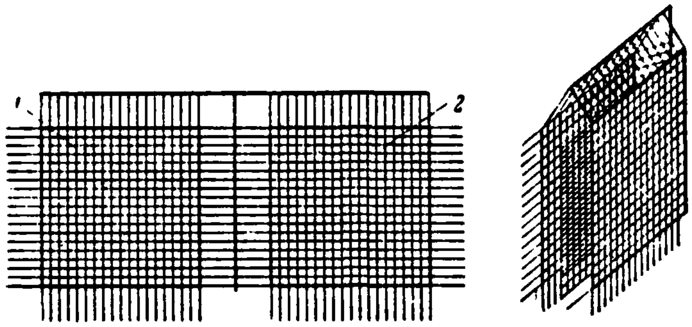

Fig. 6. Connection of the elements/cells of the mesh scanning device/equipment.

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In view of the fact that on each photocell is focused the image of object, it is possible to carry out the independent search through the sector and circular elements/cells. In this case on one photocell is conducted the search on the angular coordinate, and on the second - on the radial. Since search on the sectors and the rings is conducted simultaneously, it is possible to substantially decrease the time of the search for object.

Upon the entry/incidence of the image of object to any radial or circular element/cell occurs a substantial change in the parameters of this element/cell in comparison with the parameters of remaining elements/cells. In the switching device/equipment in the value of the

signal, which enters from this element/cell, it is possible to establish/install the location of the image of object on this element/cell. In the case of the presence of object in the field the signals, obtained from each of sensing elements examined, have impulses/momenta/pulses of detection. Comparing these signals with the supporting/reference ones, it is possible to directly determine the coordinates of object φ and ρ (see Fig. 7).

Device/equipment with this operating principle can be carried out, also, for scanning of rectangular image. In this case (Fig. 8a, b) with the aid of the optical elements/cells simultaneously on two photocells 3 and 4 is focused the image of object. Each photocell is made from the isolated/insulated photosensitive strips. In this case both photocells are established/installed so that the strips of the first (1) are perpendicular to the strips of the second (2).

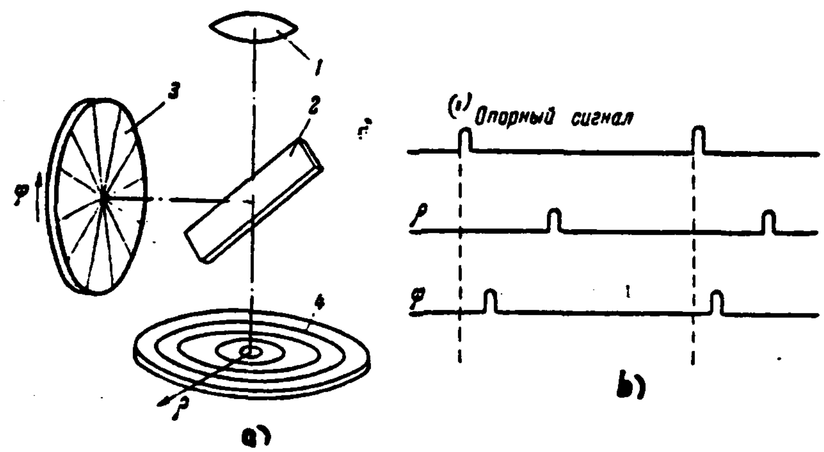

Fig. 7. Device/equipment of zonal scanning with circular sensing element.

Key: (1). Reference signal.

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Conclusions/outputs from all strips are given to the electromechanical (or electronic) commutator. In this case strips of both photocells are commutated simultaneously, and by the obtained signals it is possible to judge the location of the image of object on the square raster.

The enumerated versions of search-servo devices/equipment possess simplicity and reliability, small overall sizes and weight.

Let us switch over to the selective circuits of zonal scanning, made with the use of elements/cells of fiber optic/optics. Let us examine briefly operating principles, methods of production and fundamental characteristics of the elements/cells of fiber optic/optics, utilized in scanning devices/equipment [25-27].

If we illuminate one end/face of sufficiently thin glass rod, then the large part of the light/world, penetrating in it, which falls on lateral surfaces, cannot leave from the rod as a result of total internal reflection. Light/world repeatedly is reflected from the lateral surface of rod and emerges from its opposite end/face. The latter occurs if the diameter of rod is very small. This phenomenon in principle is not changed to that moment/torque, until the diameter of rod becomes comparable with the wavelength of light/world. Such characteristics possess the filaments with a diameter of 5-50 μ. The light/world, which entered this filament, cannot leave it through the lateral surface and because of total internal reflection is transferred to the distant end/lead. In this case the only difference, introduced by the diameter of filament, consists of an increase in the number of reflections per unit of the length of light guide.

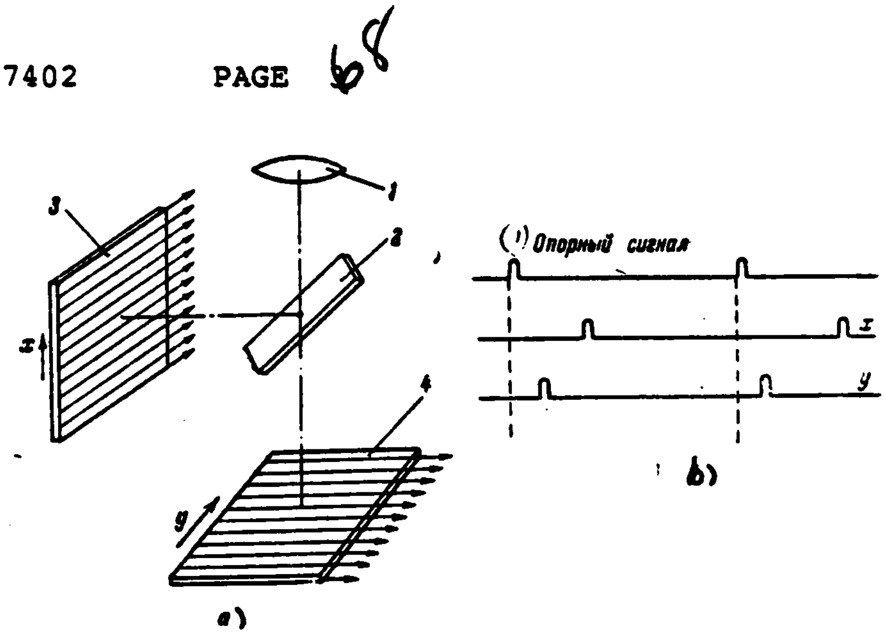

Fig. 8. Device/equipment of zonal scanning with rectangular sensing element.

Key: (1). Reference signal.

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With the considerable decrease of the diameter of filament begins to be manifested the diffraction of light. If the diameter of filament approaches a wavelength of light/world, the part of the energy departs for the surface of filament.

For the image transmission is necessary the dense laying of filaments to the bands. If in this case two adjacent filaments are arranged/located at a distance smaller than half of wavelength, then

light/world is drawn through of one filament into the adjacent. The tightly arranged/located in the band filaments are contacted with each other, and the infiltration of light/world into the adjacent filaments is observed not only on the very line of contact of filaments, but also in that region where the thickness of the air space between them is less than 1/2 λ.

The infiltration of light/world considerably worsens/impairs the contrast of image and reduces resolving power. Therefore filaments must be insulated from each other by thin shell of transparent material with the refractive index smaller than in filaments themselves. Furthermore, this shell must ensure smoothness and finish of the surface of the light-conducting center of filament, necessary for the exception/elimination of the light losses with the complete by internalization reflection.

Plastics, as a rule, as a result of the presence of the determinate structure of material, scatter light/world, which makes them unsuitable for the light guides of large length. The best material for the sheathing of filaments proved to be the optical glasses whose advantage - the wide selection of refractive index.

The flexible glass fibers, regularly packed in the band, transfer image, also, when band folds. If filaments are packed

completely freely relative to each other (with exception of ends/leads), then band proves to be very flexible. If to one end/lead of the band is attached the objective, which projects image to the end/face of band, and opposite end/face is examined through the ocular with certain increase, then is obtained flexible periscope.

In the bands of a good quality the light/world, which entered through the lateral surfaces, departs only through the surfaces, parallel to fiber axis. Consequently, the light/world, which entered through the lateral surfaces of band, cannot leave through its ends/faces and does not participate in the creation of mist of scattered light, which is superimposed on the useful image. This condition is disrupted in the case of bands with the rough surface of filaments, bands whose ends/faces are not perpendicular to filaments, and for the conical bands, since in them the part of scattered light, falling on lateral surfaces or ends/faces of band, can undergo total internal reflection.

Since each separate filament possesses property to summarize the entering it luminous fluxes, then any part with the diameter smaller than the diameter of filament, cannot be transmitted separately from its environment/encirclement. Consequently, permission/resolution during the image transmission on the motionless band is limited to the diameters of separate filaments.

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Some simple examples of the use of elements/cells of fiber optic/optics in the scanning devices/equipment are given in Fig. 9. In Fig. 9a is illustrated the use of a fiber transformer of image for changing the configuration of image, which can transmit usual (round) camera tube; Fig. 9b depicts the fiber transformer of image, which makes it possible with the aid of the rotating photoelectric commutator to scan linear or rectangular rasters.

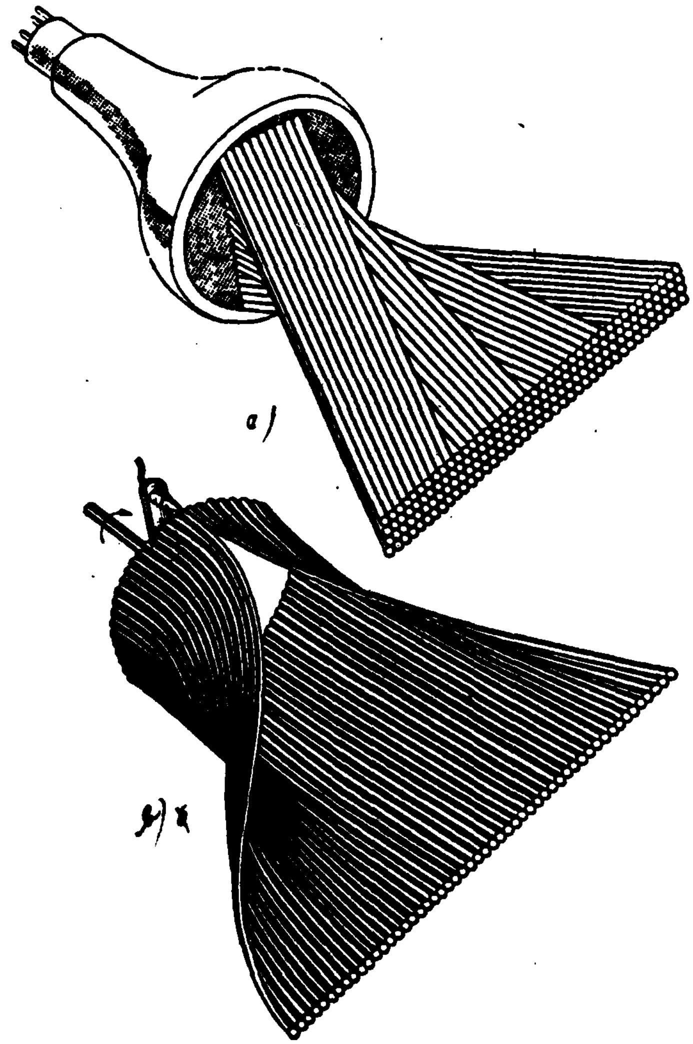

Fig. 9. Examples of the use of elements/cells of fiber optic/optics.

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The use/application of a fiber optic/optics in the scanning

devices/equipment presents one of the promising trends of the development of the search and search-servo scanning devices/equipment. The use of elements/cells of fiber optic/optics makes it possible sufficient simply to solve the problems of separation into several information tracks, which goes from one element/cell of field, and connection into one channel of light information from different sections of the controllable/controlled/inspected field. This makes it possible by simple means to create the fundamentally new scanning devices/equipment whose construction by previously known paths led to the very bulky solutions.

The author together with O. I. Karyagin developed the search scanning device/equipment in which are used the elements/cells of fiber optic/optics [28].

The scanning devices/equipment with the fiber optic/optics, the images intended for the development/scanning through any predetermined trajectory, find wide application in different areas of science and technology. However, any scanning device/equipment of such type realizes a consecutive survey of each point of the controllable/controlled/inspected field along any trajectory. Thus, for obtaining the representation about the controllable/controlled/inspected field it is necessary to look over

in the specific sequence each point of field. One of the basic indices of quality of the scanning device/equipment is the time interval, during which is realized one cycle of scanning field. For the case when in the field is found (it is located) only one object, utilizing a method of zonal scanning, it is possible to shorten the time of the survey of the controllable/controlled/inspected field into dozens of times in comparison with the usual consecutive scanning. In this case the controllable/controlled/inspected field is divided/marked off in the sections of the specific form, which consist of certain quantity of elements/cells of field. Field is examined/scanned not on the elements/cells, but immediately in the picture lines, moreover simultaneously in the mutually perpendicular rows (for example, in the vertical and horizontal rows in the case of rectangular raster). In this case the gain in the time grows/rises with an increase in the number of points (image elements) in each row. This can be explained as follows. Let us assume that it is necessary to scan the square field, which consists of 100 elements/cells, arranged/located on 10 in each horizontal row and on 10 in each vertical series/row. Each row it is combined into one zone, each series/row is also combined into one zone. Thus, in the square field will be obtained 10 zones, formed of 10 horizontal rows, and 10 zones, formed of 10 vertical series/rows. Zones are scanned by two scanning devices/equipment simultaneously. Let us assume that to the survey of each element/cell of field it is necessary Δt s.

Then for the consecutive scanning of entire field by one scanning device/equipment are required 100 Δt s.

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In the case of using the proposed zonal method for the complete scanning of this field it is necessary to expend in all 10Δt s. This occurs as a result of the fact that simultaneously is scanned the field in the mutually perpendicular rows (it must be noted that in the example examined the time of the survey of one zone or row is equal to the time of the survey of one element/cell). With the increase of a number of elements/cells in the square frame to 10 thousand gain in the time will increase to 100 times, etc.

As already mentioned, in the developed coupler between the sensitive screen and the scanning elements/cells is realized with the aid of the fiber optic/optics. The scanning device/equipment consists of the following basic assemblies (Fig. 10): 1 - optical system, which focuses the image of the controllable/controlled/inspected field to the rectangular end/face of fiber transformer; 2 - fiber transformer, intended for the separation of image into the elements/cells and the zone; 3 and 4 - photoelectronic dissectors, which realize scanning zones; 5 - the scaling circuit, intended for the formation of control signals; 6 - electron-beam indicator for the

visual determination of the position of the unknown point in the field; 7 - power supply unit.

Fiber transformer 2 is made from the optical filaments, which are light guides. In it are used the bands from the glass conical filaments, which have irregular laying. In this case each band is divided into two light-wire channels (Fig. 11). Each band from the side of receiving screen is placed regularly in the general/common/total band with the square section, which has, for example, 10 bands on the vertical line and 10 on the horizontal (with the total number of bands, equal to 100).

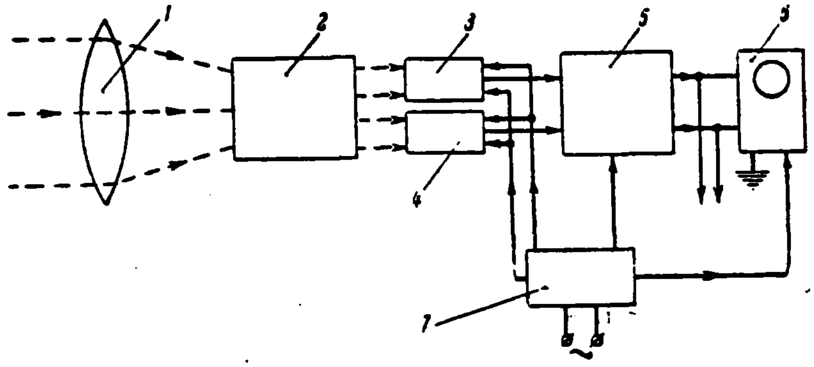

Fig. 10. Block diagram of selective circuit with the fiber optic/optics.

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The frontal end/face of fiber transformer, the receiving screen being, are fastened, is impregnated with special resin and is polished. The second ends/leads of the fiber bands are processed as follows. In one band of round cross section are united all first halves of the claws of all bands of horizontal row. So are united all first halves of the light guides of the subsequent horizontal rows. The second ends/leads of the bands of the first vertical series/row of receiving screen also are united into one band of round cross section. Analogously are united all second halves of light guides, which go from each vertical series/row of receiving screen. Thus, at the output of fiber transformer are obtained 10 bands from the horizontal rows and 10 from the vertical series/rows.

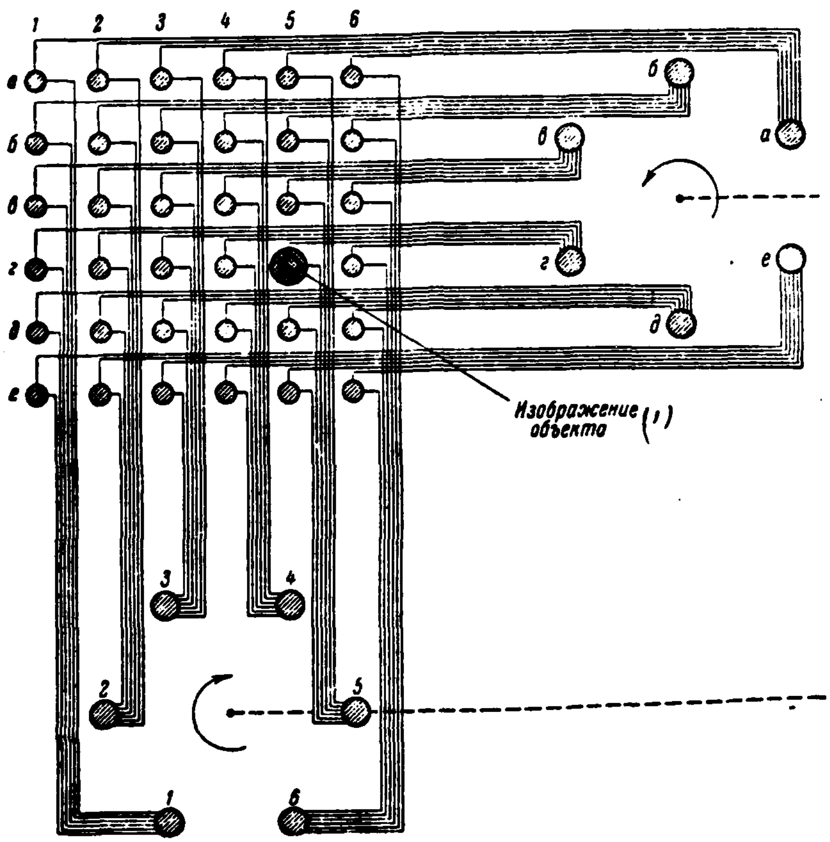

Fig. 11. Diagram of connection of the light-wire filaments between the receiving square screen and two photoelectric commutators.

Key: (1). Image of object.

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The ends/faces of 10 bands, which go from the horizontal rows, are arranged/located along the circle/circumference in one plane

close to each other. Analogously are placed the ends/faces of the bands, which go from the vertical series/rows. For the strength into the middle of circular bands can be packed the rods from opaque material (ebonite, Textolite, etc.).

Entire fiber transformer consists into the opaque housing with one square window for the receiving screen and two circular windows for the circular exit bands of light-wire filaments.

Dissectors 3 or 4, intended for the photoelectronic commutation of signals, are made with the use of photomultipliers, equipped with the deflection systems. To the windings of the latter are supplied the variable/alternating sine voltages, shifted relative to each other on the phase on 90°. As a result appears the rotating magnetic field, which causes the rotation of the electron image, analogous to the optical image, designed on the input screen of photomultiplier. In this case the electron image rotates relative to the axis of dissector so that any point of it describes a circle. If on the periphery of the input screen of dissector ring arranged/located the exit ends/faces of the light-wire bands of fiber transformer, then during the rotation of electron image to the opening/aperture of the diaphragm of dissector will consecutively/serially fall electrons from the sections of photoelectric cathode, situated against each of the exit ends/faces of bands. At that moment of the time when on the

anode of dissector fall the photoelectrons, which correspond to the light guide of that horizontal row of the receiving screen of fiber transformer, on which is arranged/located the image of object, in the signal of dissector is formed/shaped the impulse/momentum/pulse.

Is analogously arranged and works the node/unit of the commutation of the light guides, which correspond to the vertical rows of the receiving screen of fiber transformer.

Comparing the signals obtained from two dissectors with the reference signals, supplied to the developable systems, it is possible to continuously determine the coordinates of the unknown object. In this case it is necessary to note that the scanning in the horizontal and vertical rows is conducted by both dissectors simultaneously; therefore both signals, which carry information about the coordinates of object, are formed/shaped also simultaneously.

Output signals from the scanning dissectors bear information about the bias/displacement of object. These signals after passage through the converting block/module/unit (in which is conducted the recalculation of the origin of coordinates) can be given to the actuating elements, which realize the appropriate displacements of the optical axis of servo system.

The scanning device/equipment examined can be made, also, with the circular receiving screen. In this case is conducted simultaneous scanning along radii and along the circles/circumferences of different diameters (Fig. 12).

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The filling with the bands of circular input screen can be made two types: in the first case the filling of entire input screen is realized by bands of identical diameters. In the second case in the central region of circular input screen are arranged/located the bands, which have smaller diameters than the bands, arranged/located on the periphery.

Each band, leaving the element/cell of input screen, is divided in two. First halves of bands from the elements/cells of screen, arranged/located on a constant radius, are connected up general/common/total band. Thus are connected the light-wire filaments, which go from all elements/cells of each circle/circumference whose center is arranged/located on the axis of receiving screen. Second halves of bands from the elements of radial line also are connected up one band. Analogously are connected the light-wire filaments, which go from all elements of each radial line. This connection of filaments is realized, when the diameters of the

filaments, located in center, are less than the diameters of filaments, which are located on the periphery of screen. If are used the filaments of identical diameters, then second halves of bands are connected together in the form of sector elements/cells. Secondary bands are connected with the photoelectronic commutators in this case just as with the rectangular input screen.

The major advantage of the scanning device/equipment examined is that that it allows when, in the field, one object is present, to considerably decrease the time of search by the simultaneous scanning of the image of field in two mutually perpendicular directions with the retention/preservation/maintaining of the sufficiently high resolution. In this case is conducted not the consecutive piece-by-piece scanning of all sections of field, but simultaneous perception by two sensing elements of the whole bands of the image of field in two mutually perpendicular directions.

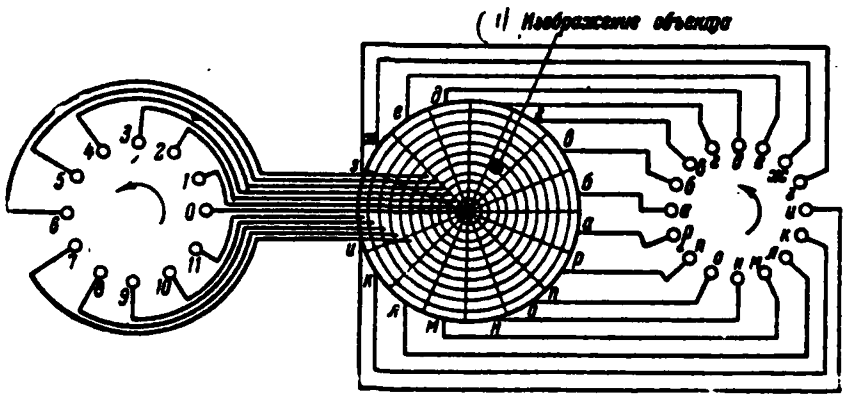

Fig. 12. Diagram of connection of the light-wire filaments between the circular receiving screen and two photoelectric commutators.

Key: (1). Image of object.

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Chapter 6.

OPTICAL-MECHANICAL SEARCH SCANNING DEVICES/~~EQUIPMENT~~ WITH THE FLEXIBLE ELEMENTS/~~CELLS~~ OF DRIVE.

Is at present developed the series/row of the optical-mechanical scanning devices/equipment in which the scanning elements/cells complete complicated three-dimensional/space displacements [9-10]. The electric drive of such devices/equipment usually is fulfilled with the use of complicated mechanical linkages. Most characteristic for this group is the device/equipment in which the draw tube with asymmetrically established/installed lens completes rotation around its own axis, and also around the second axis, inclined toward the first [9]. These motions are communicated to the scanning draw tube by fairly complicated gear drive. As a result of this three-dimensional/space displacement of tubule on the motionless photocell occurs scanning/sweep of image along the rotational-rotational socket trajectory (see Fig. 1).

As a rule, the block diagram of the optical-mechanical scanning device/equipment of such type consists of the following basic assemblies:

1) optical system, which in each specific case is different combinations of optical elements/cells (objectives, prism, mirror, etc.);

2) the trajectory mechanism, which ensures the three-dimensional/space displacement of one or several elements of optical system, which realize scanning;

3) converter (reducer) - in the majority of the cases of pinion drives, which ensure transmission to the trajectory mechanism of one or several motions from the engine (combination of rotary or rotary and forward motions);

4) electric drive;

5) sensing element;

6) electrical circuit.

Trajectory mechanisms and actuators of the existing optical-mechanical scanning devices/equipment are realized, as a rule, on the basis of the complex of cam, gear and linkage elements/cells. Because of this such devices/equipment possess the increased complexity and low reliability three prolonged operations.

Are recently developed the flexible elements/cells, utilized in different drive assemblies. Work [29] examines the basic ways of calculation and engineering such flexible elements/cells whose use makes it possible to considerably simplify the block diagrams of the scanning devices/equipment, since in this case it is possible to create very simple reducers with the large gear ratios, and also simple transmissions between the inclined (intersecting) axes.

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Let us examine several scanning devices/equipment, developed by the author together with I. K. Mel'nichenko [30].

The operating principle of the scanning device/equipment, which realizes a socket rotational-rotational trajectory and based on the use of flexible elements/cells, is reduced to the following. Fig. 13

shows the scanning mechanism, which consists of draw tube 3, which rotates in drum 2. The latter also completes rotary motion in housing 1 relative to its axis of symmetry. The rotational axis of draw tube is inclined with respect to the rotational axis of drum and interesects it at point C under a certain constant angle α. In the draw tube is established/installed lens 4 with the displaced optical axis. As a result of the fact that the rotor of engine is connected with the elements/cells of drive with those rotating by draw tube and with drum, rotor is made hollow and on its fixed axis is arranged/located sensing element.

As a result of the simultaneous rotation of the tubule and drum occurs this displacement of the analyzed image relative to motionless sensing element 6, with which is completed the scanning/sweep along the rotational-rotational trajectory (see Fig. 1). When the speed of rotation of draw tube in n of times exceeds the angular rate of rotation of drum and angle α_1 between the axis of lens and the rotational axis of draw tube it is equal to angle α_2 between the axis of draw tube and the axis of drum, the device/equipment examined will realize a socket rotational-rotational trajectory with the relationship/ratio of the parameters $2r=R$ (see Fig. 1).

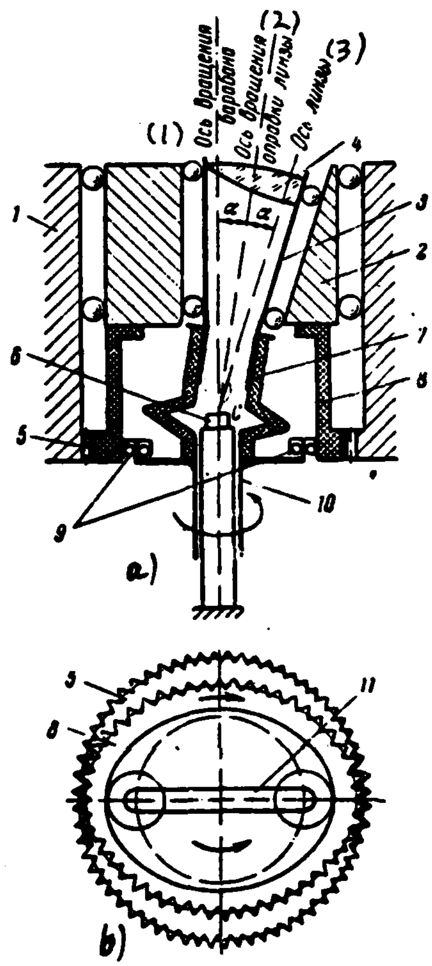

Fig. 13. Schematic diagram of the optical-mechanical scanning devices/equipment with the flexible elements/cells drive.

Key: (1). Rotational axis of drum. (2). Rotational axis of mount/mandrel of lens. (3). Axis of lens.

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For rotating the inclined draw tube with the same angular velocity such as has engine, is utilized flexible coupling 7, made, so as to ensure the best transmission of the torsional moment between the inclined axes. The cylindrical form of flexible element/cell with the corrugation in the middle section in this case is most rational, since the bending occurs in the plane, perpendicular to the axes of draw tube and motor. This connection virtually does not play and provides the synchronism of the rotation of draw tube and shaft of engine.

The rotation of drum 2 whose angular velocity in n of times is lower than the velocity of draw tube, is realized with the aid of the special device/equipment, basic part of which is the flexible element/cell, called "flexible gear" [29].

This unit of drive includes the following:

flexible cylinder 8, made in the form of the beaker, attached to drum 2; in the lower part of the flexible beaker is serrated rim;

motionless metallic gear 5, with which is engaged the flexible gear, arranged/located on flexible cylinder;

roller deformator 11 of flexible gears.

Fig. 13 shows the deformator made in the form of the rod, rigidly connected with the shaft of 10 engines. At the opposite ends/leads of the rod are attached rollers 9. The rod of the deformator has the same angular velocity, as the rotor of engine. Rollers 9, resting from within into the walls of flexible gear 8, give to it the form of ellipse. The teeth of the flexible wheel, which lie on both sides of transverse, enter into engagement with the hard/rigid gear. In this case teeth of both wheels, arranged/located not on the transverse, emerge from engagement (Fig. 13b).

Teeth on the flexible and hard/rigid gears have identical space, but on the flexible gear of teeth it is somewhat less than on the hard/rigid. Since in the device/equipment in question is applied a deformator with two rollers and in the engagement simultaneously are located the teeth of two diametrically opposite sections of flexible gear, it must be symmetrical. The difference in a number of teeth on both wheels must compose the integer, multiple from a number of rollers, i.e., 2, 4, 6, etc. Pitch circle of the teeth of flexible gear is done less than pitch circle of the teeth of hard/rigid gear, to the value, which depends on difference in a number of teeth.

During the rotation of the deformator 11 flexible wheel acquires

oscillatory, wave motion and rotates in the opposite direction. In this case occurs the considerably retarded rotation of flexible gear. Each complete revolution of the deformator produces the rotation of flexible wheel to certain angle as a result of the difference in numbers of teeth on both wheels.

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If the deformator has constant angular velocity, then flexible wheel acquires certain angular velocity, but considerably retarded and opposite direction. In this consists the action of the device/equipment, which leads to the rotation the drum of 2 scanning systems.

Thus, the scanning device/equipment in question contains as the drive two flexible elements/cells, of which one is flexible membrane/diaphragm type connection 7, and the other - a flexible cylinder with the made on it gear, utilized for the reduction of the engine speed.

For shaping of the signals of synchronization, necessary for reconstruction of image of the controllable/controlled/inspected field on synthesizing the block/module/unit, in the device/equipment are four inductance pickups. The latter are established within 90° in

the circle/circumference, coaxial with the optical axis. Diametrically opposite sensors are connected in series, and signals from them after amplification are supplied to two deflection coils of the block/module/unit, which synthesizes image.

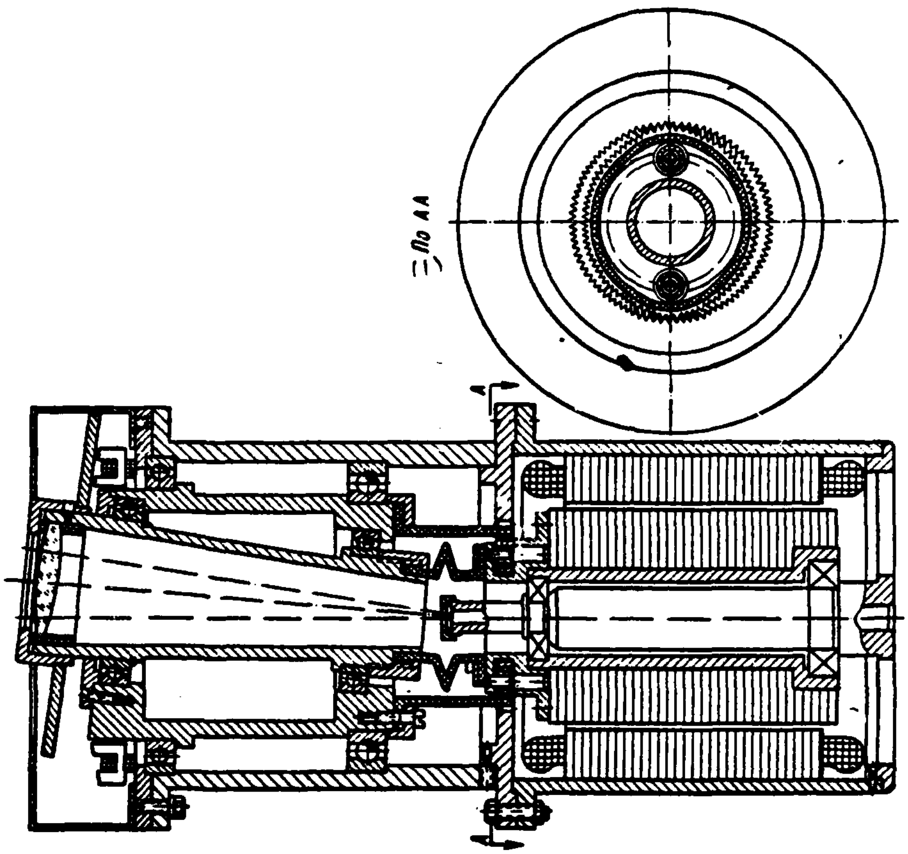

Fig. 14. The design concept of the optical-mechanical scanning device/equipment with the flexible drive, which realizes scanning along the socket rotational-rotational trajectory.

Key: (1). On.

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During the motion of draw tube with the lens the special metallic plate, fastened/strengthened to the draw tube, completes

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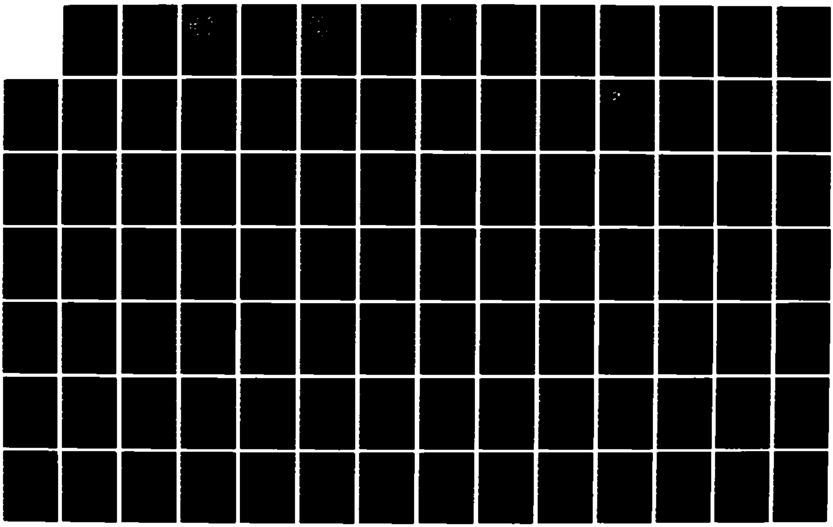

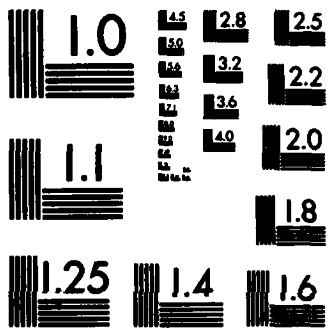
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three-dimensional/space displacements. In this case changes the distance between the plate and the inductance pickups, which forms/shapes in the signal generators, necessary for the displacement of electron beam in the cathode-ray tube synchronously with the displacements of the optical scanning beam.

The general/common/total design concept of the scanning device/equipment, developed in IAT, which realizes scanning along the socket rotational-rotational trajectory, is represented in Fig. 14. Its basic advantage is simplicity, caused by the use/application of flexible elements/cells of drive. Furthermore, weight and volume of device/equipment substantially decrease in comparison with the analogous optical-mechanical devices/equipment with the gear drive.

In IAT is developed also the version of the optical-mechanical scanning device/equipment with the flexible elements/cells, which realizes scanning along spiral trajectory [30]. Structurally/constructurally this device/equipment is made as follows. In housing 1 (Fig. 15) is established/installed the stator of electric motor 2 whose rotor 4 is pressed to drum 3.

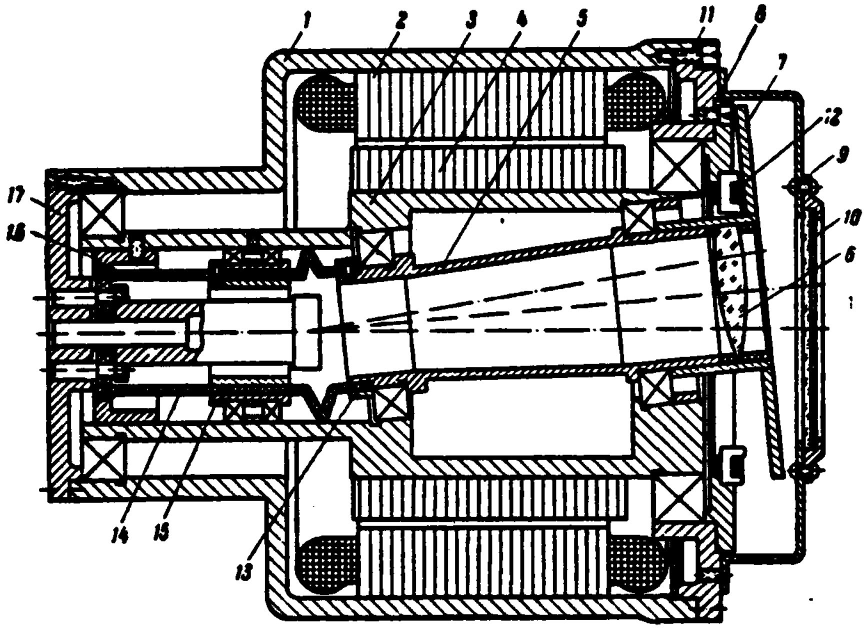

Fig. 15. The design concept of the optical-mechanical scanning device/equipment with the flexible drive, which realizes scanning along the spiral rotational-rotational trajectory.

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One neck of drum is arranged/located in the bearing, established/installed in the draft of the housing. Front/forward end of the drum is established/installed in the bearing, placed in the cover/cap of housing. In the bore of drum at angle to the axis of its rotation in two antifriction bearings is established/installed draw tube 5 with placed in it lens 6. On the front/leading neck of draw tube it is established/installed disk 7, intended for shaping of the

signals of synchronization. Jacket/case/housing 8 with window 9-10 protects disk from the mechanical damages. In cover/cap 11 under the disk are placed four inductance pickups 12, located in two mutually perpendicular planes.

To the smaller neck of draw tube with the aid of ring 13 is fastened flexible element/cell 14, prepared in the form of long cylinder with the corrugation, which performs role by the membrane/diaphragm of clutch. In the middle part the flexible cylinder is rigidly fastened with bushing 15, established/installed on the bearings and supporting flexible cylinder of the longitudinal displacements.

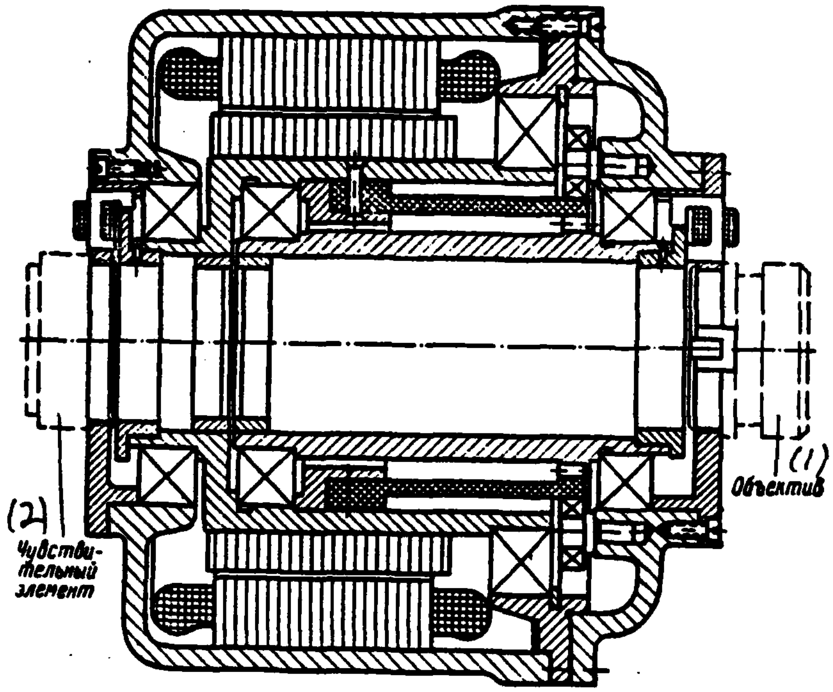

Fig. 16. Optical-mechanical scanning device/equipment with the flexible drive and with two diaphragms with the figure gashes.
Key: (1). Objective. (2). Sensing element.

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Hard/rigid ring gear 16 enters into engagement with the toothed rim, made on the flexible cylinder. Rollers realizing this engagement are established/installed on the motionless central rod. Hollow rod is made together with cover/cap 17. Sensing element is placed on the end/face of this rod.

Basic differences in this device/equipment in comparison with

preceding/previous are reduced to the following. Drum 3 obtains the angular rate of rotation, equal to the speed of rotation of the rotor of electric motor. The rotation of draw tube 5 whose angular velocity for the execution of spiral trajectory must be somewhat lower than the angular rate of rotation of drum, is realized with the aid of the device/equipment with the flexible elements/cells, similar examined above. The relationship/ratio of numbers of the teeth of hard/rigid and flexible wheels provides obtaining the required reduction of the angular velocity of drum.

In this device/equipment two rollers of the deformator are established/installed on the fixed axis, moreover the gear of flexible element/cell, connected with inclined draw tube, is rolled on the motionless metallic gear, arranged/located on the rotor. Flexible element/cell 14 is centered in the opening/aperture of drum by ring 15, which rotates in the bearings. The role of the membrane/diaphragm of flexible element/cell in this device/equipment is the same as in preceding/previous, the transmission of rotational moment to the draw tube, arranged/located at angle to the rotational axis of drum and flexible cylinder.

The signal-shaping circuit of synchronization in this scanning device/equipment is the same and in that examined above.

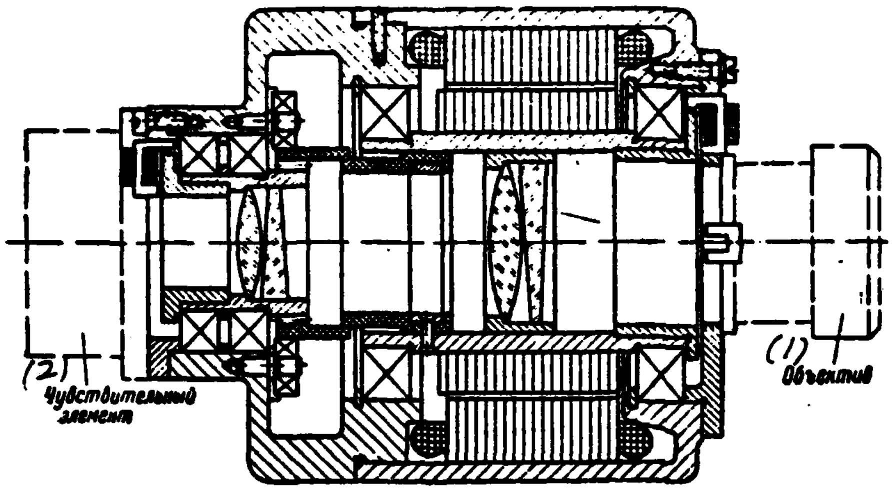

Fig. 17. Optical-mechanical scanning device/equipment with the flexible drive and two optical wedges.

Key: (1). Objective. (2). Sensing element.

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It has considerably smaller overall sizes, which is reached by coincidence in one node/unit of the rotor of electric motor and scanning drum. In this case considerably decreases the length of the central supporting/reference rod on which is arranged/located the photocell. This is essential advantage, since is caused an increase in the accuracy as a result of the decrease of the effect of the oscillations of supporting/reference rod on readings/indications of device/equipment.

Fig. 16 and 17 give two versions of the scanning optical-mechanical devices/equipment in which for the scanning it is necessary to communicate to two network elements rotary motion with different angular velocities. For this are utilized in the drive flexible elements/cells.

The scanning device/equipment, represented in Fig. 16, has two optical wedges, that rotate with different angular velocities. In this case as a result of the birefringence of radiations/emissions depending on the relationship/ratio of angular velocities of both wedges can be obtained as spiral, that and socket of the trajectory of scanning.

The device/equipment represented in Fig. 17 has two diaphragms, which rotate with different numbers of revolutions, moreover on one diaphragm is a radial gash, also, on the second - gash, made on the Archimedes spiral. During rotation of both diaphragms with the differing little velocities is realized the spiral trajectory of scanning.

From the given illustrations it is evident that the use/application in these scanning devices/equipment of drive with the

use of flexible elements/cells makes it possible to carry out sufficiently simple and acceptable for the practice devices/equipment, whereas use for these purposes of gear reducers leads to very bulky solutions [9].

Thus, in conclusion it is necessary to note that on the basis of the use of elements/cells of the flexible drive it is possible to create the series/row of the new simple and original optical-mechanical scanning devices/equipment. In the case of using the flexible elements/cells in reducers and drives of the optical-mechanical scanning devices/equipment their kinematic schemes are considerably simplified. In this case in a number of cases, on of the known kinematic schematics of the scanning devices/equipment it is possible to create the new original and substantially simplified circuits of the scanning devices/equipment.

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Section III.

ELEMENTS OF THE SERVO PHOTOELECTRIC AND OPTICAL-MECHANICAL SCANNING SYSTEMS.

Chapter 7.

PRINCIPLES OF THE CONSTRUCTION OF THE OPTICAL-MECHANICAL AND PHOTOELECTRIC FOLLOWERS.

In many fields of science and technology frequently appears the problem of tracking the sources of luminous radiation. For example, in astronomy at the prolonged photo-exposures is necessary to avoid "eroding/scouring" of the obtained photograph a precise direction of telescope in the section of sky being investigated. For this is utilized the auxiliary tracking telescope, rigidly fastened with the basis so that their optical axes to. This telescope assembles radiations/emissions from the "control" star (planet). During its shift relative to the optical axis of the tracking telescope (for example as a result of the effect of atmospheric refraction, error in the clockwork of drive, etc.) the sensor, connected with this telescope develops the control signal which is utilized in the servosystem for maintaining the required orientation of basic telescope.

Tracking the sources of luminous radiation recently begins also extensively to be used for automatic navigation and orientation in aviation and marine equipment.

Different devices/equipment, which realize tracking in the optical range, can be divided into the optical-mechanical and the the photoelectric.

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Lying as the basis of the action of the optical-mechanical search scanning devices/equipment, intended for the definition of the disagreement/mismatch between the optical axis of system and the direction to the object of tracking, are the following principles:

1) the use of interruption of the luminous flux for the definition of disagreement/mismatch with the aid of:

the rotating modulating disks, which have the special form (shaping on the Archimedes spiral, semidisks, etc.):

the rotary disks, which have the special shaping of the modulating bands (disks, form and the size/dimension of bands of which they change both on the radius and on the angle of rotation);

the modulating grid, which accomplishes complicated

displacements relative to the image of object;

image drifts relative to the modulating grid (device/equipment with the rotating optical wedges, the prisms of the Doves, the flat/plane and concave mirrors, etc.);

2) the use of separation of the luminous flux (by means of the prisms or the mirror pyramids) for determining the disagreement/mismatch with the aid of:

moving and driving elements for the commutation of the divided luminous fluxes into one or several photocells (device/equipment with the rocking mirrors, with optical-mechanical commutators, by selectors and by the prisms of the Doves);

the methods of the simultaneous recording of the intensities of the divided luminous fluxes (device/equipment with four sensing elements, with the roof prism, etc.).

The operating principles of the photoelectronic servo scanning devices/equipment are based on the use:

1) different types of image converter tubes for imparting of rotary motion to image the object relative to the motionless

modulating grids;

2) dissectors with figure openings/apertures in the diaphragm (circular, square, cross-shaped, in the form of sector discs, etc.) and different types of the trajectories of scanning (circular, line-by-line, square, cross-shaped, etc.);

3) the effect of lateral photo current;

4) the complex of the usual or differential photoresistors, connected with the special selective diagrams.

As was already noted, the optical-mechanical followers can be made with the use of different rotating disk modulators of the luminous flux, which goes from the object of tracking. These modulators realize such a modulation of the luminous flux, which passes to the photocell on different sections of the round controllable/controlled/inspected region of field, in which it is possible to obtain information about the position of object. The most widely used type of such modulators is rotating semidisk [31]. For the isolation/liberation of small objects against the background of the large/coarse image details of the controllable/controlled/inspected field are developed also the versions of half-disk modulator in which one-half of disk is made

semitransparent and the other half one consists of the series/row of transparent and opaque sectors. Both halves of this disk have identical total transparency; therefore in the presence only of background (in the absence of object) signal is absent.

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This permits implemention of a three-dimensional/space selection and to simultaneously have symmetrical waveform, which simplifies the schematic of device/equipment. Are developed also the followers of which one half of the modulating disk consists of the spiral or zigzag alternating black and white bands, and the other - of the same bands, which have the form of circle/circumference [32]. This is done also for the realization of three-dimensional/space selection. It is necessary to note that the enumerated above modulating disks make it possible to determine only the direction of the shift of object. So that with the aid of the such devices/equipment it would be possible to determine direction and amount of the shift of object, to the sector bands of disk is given modulation in two directions - on a radius and on the angle of rotation [33].

Is developed also the series/row of the followers, in which are utilized two rotating disk modulators [34-35]. Disks have different number of bands (or primes), which have different length, and rotate

with different number of revolutions. They are established/installed so that the bands intersect the image of object in two perpendicular directions. In this case in form of modulation of signal are determined the value and the direction of the shift of object.

Is developed also the series/row of the devices/equipment of analogous operating principle, in which modulation of the luminous flux is created as a result of oscillatory motions of two shutters/valves, which have rectangular slots [36]. Such devices/equipment in a number of cases possess some advantages, among which basic are small overall sizes.

There is a group of the followers in which the modulating grid completes complicated rotary-translational [37] and differential motions [38]. In this case depending on the direction of the shift of object changes the frequency spectrum of the signal, formed/shaped on the photomultiplier. The direction of the shift of object is determined by the comparison of the obtained signal with the reference signal. However, such followers have the increased complexity of the drive of disk modulator.

Large group compose the devices/equipment in which the error signal is formed/shaped as a result of rotating the image of object relative to the motionless modulating disk. During the shift of the

image of object from the optical axis the circle/circumference, in which it rotates, it becomes eccentric with the center of the modulating disk. In this case the direction of shift can be determined by the comparison of the obtained signal with reference signal [39, 40]. In these devices/equipment the rotation of the image of object is realized with the aid of the rotating optical wedges or the mirrors. In some followers of this type photocell it has cross-shaped form, combining in itself the functions of modulator and photocell, which simplifies diagram [41]. During the intersection of this photocell with the image of object rotating with the aid of the mirror is formed/shaped the signal in form of which are determined the direction and the amount of the shift of object.

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In a number of the devices/equipment of this class the modulating grid has a form of square, and the scanning mirror moves the image of object along square trajectory [42]. In this case, when object is located on the optical axis of follower, the trajectory of the motion of the image of object is located within the square opening/aperture of diaphragm and radiation/emission from the object continually falls on photocell. If object is set out of center of system, then its image will describe the square trajectory, which partially falls on diaphragm, and partially on the photocell. In this case in form of

the signal formed/shaped on the photocell it is possible to determine disagreement/mismatch.

Let us examine the group of the optical-mechanical devices/equipment, in which for the purpose of the determination of disagreement/mismatch is realized the division of the luminous flux, which goes from the object, by several flows. In the majority of the devices/equipment of this group for data finding about the shift of object along two coordinate axes is utilized tetrahedral mirror pyramid with the axis, arranged/located along the optical axis of system. Depending on the direction of disagreement/mismatch to the different faces of pyramid come the luminous fluxes of different intensity on relationship/ratio of which it is possible to determine the direction of disagreement/mismatch. From each face of this pyramid the radiations/emissions are supplied either to separate photocells [43], or to one general/common/total photocell [44]. In the latter case for the consecutive commutation either the separation of signals is utilized the phasing commutator, or disk modulator, and frequency discriminator.

An overall deficiency/lack in all optical-mechanical followers examined is the presence of moving elements/cells, that somewhat decreases the service life of the work of such systems and decreases their reliability during the prolonged operation.

Let us switch over to the photoelectronic servo scanning devices/equipment. In these devices/equipment with the aid of image converter tubes or photoelectric dissectors to the photoelectronic image of object are given different displacements relative to the opening/aperture of diaphragm, which has various forms [45-47]. By the scanning motions of various forms (rotary, oscillatory, cross-shaped) in the final analysis is created modulation of photoelectronic flows on which it is possible to determine disagreement/mismatch. The scanning motions of some of the photoelectronic followers are similar to analogous motions in the examined above optical-mechanical followers. After resolution in the Fourier series of the signal, obtained from the dissector, it is possible in terms of presence and absence of specific components to determine direction, and in certain cases and the amount of the shift of object.

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The same class can be referred the devices/equipment, in which the shift of object is determined with the aid of the complex of differentially connected sensing elements. Special simplicity reach such devices/equipment when in them are utilized special differential

photoresistors [48-49].

Developed comparatively recently the new very simple photocell, which possesses sensitivity to the displacements of the source of luminous energy. In this element/cell the shift of object determines the values of lateral photo currents between four lateral and one central electrodes [50]. However, thus far the accuracy of such elements/cells is low.

From the analysis of different operating principles of followers it is possible to make conclusions about promising trends of their development. As a result of the great variety of the fields of application of such devices/equipment and differences connected with this in those presented to them to requirements, it is difficult to indicate the good ones among the operating principles examined. Thus, for instance, apparent simplicity of the photoelectronic scanning devices/equipment becomes complicated by the need for the presence of the special supplies of power and generators of deflecting voltages. These blocks/modules/units in the majority of the cases are absent from the optical-mechanical followers, but in them there are the lowering reliability rotating parts. In the same devices/equipment where both the qualities (simplicity and reliability) examined are sufficiently high, in a number of cases are observed the lowered/reduced precision indices.

Furthermore, the characteristics of such devices/equipment can still substantially change as a result of the development of new elements/cells. There is no doubt that in the course of time the characteristics are stabilized and will be explained the promising trends of the developments of such systems. However, in spite of all contradictory data, already and now it is possible to make preliminary conclusions about the prospect of some of the directions examined. Thus, for instance, apparently, are promising the photoelectronic scanning followers, devices/equipment with the complex of differential photoresistors, and also some optical-mechanical with the rotating optical elements/cells (for example, with the prism of the Doves). Are examined below the enumerated groups of the servo scanning devices/equipment.

Chapter 8.

PHOTOELECTRONIC SERVO SCANNING DEVICES/~~EQUIPMENT.~~

As it was already noted, for obtaining the information about value and direction of the shift of object it is possible to utilize the photoelectronic scanning devices/equipment of the type of dissectors.

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Combining the different forms scanning openings/apertures in the diaphragm dissector and different types of the trajectories of scanning, it is possible to create several types of the followers, which make it possible to obtain information about the shift of object. In this case depending on a form of the scanning opening/aperture and type of the trajectory of scanning occurs different modulation of the photoelectronic flows, which fall on the anode of dissector. This determines a difference in the block diagrams of followers.

As the first example let us examine photoelectronic servo device depicted on Fig. 18. The principle of its action is reduced to the

fact that to the image of object is given the rotary motion in the plane of the modulating disk. The latter is the set of transparent and opaque sector elements/cells, passing through which the luminous flux falls on photocell. In this device/equipment for rotating the optical image of object with the aid of the electromagnetic field is used electron-optical image converter (EOP). In the simplest performance it is the evacuated glass cylindrical tank/balloon, which has two flat/plane bottoms. One from the inner side is covered with photosensitive metallic film, another - with fluorescing substance, the intensity of local brightness of which is proportional to the quantity of the electrons incident onto it. Outside the tank/balloon are arranged/located the windings of the electromagnetic deflection and focusing systems. The parameters of the deflection and focusing system of EOP are designed so that during the location of the point image of object in the center of input screen on the exit screen would be formed/shaped the focus, which accomplishes uniform rotation in the circle/circumference whose center lies/rests on the axis of EOP. If the image of object on the input screen of EOP is displaced from the central point, then on the exit screen focus is circled whose center is displaced relative to axis of the EOP.

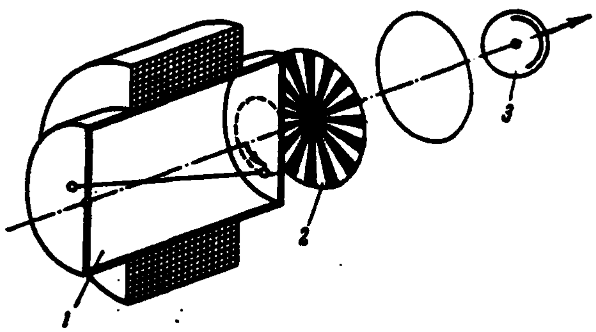

Fig. 18. Follower with special image converter tube.

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Beyond the exit screen of EOP 1 is established/installed motionless modulating disk 2 with the radial cuts after which is arranged/located photocell 3. During the rotation in the exit screen of focus in the circle/circumference concentric with axis of EOP, signal of photocell have the specific and constant modulation frequency. If the circle/circumference over which moves the focus on the exit screen of EOP, is arranged/located eccentrically relative to axis of EOP, then the modulation frequency of the signal of photocell changes. By a change in the parameters of signal it is possible to judge the shift of object [46]. This follower can be made with the modulating disk of any type (with the radial bands, with the bands, modulated in the width depending on a radius, with different mesh disks, etc.).

In one of the versions of a search-servo system as the scanning element/cell is used photoelectric dissector. The distinctive special feature/peculiarity of this dissector in the fact that its anode is made in the form of the small disk, which consists of several sectors. The image of the controllable/controlled/inspected section of field is focused to photoelectric cathode, and secondary electrons are headed toward the opposite end/face of the dissector where is located the anode, which has the form of disk with the radial ridges. In the search mode with the aid of the deflection systems, put on to the dissector, is conducted the line-by-line scanning of field. After detection line-by-line scanning ceases and are switched on the coils, which force to rotate the electron image of object and background. Electron image describes over the surface of the anode the circle/circumference, true with the center of the anodic disk when direction to the object coincides with the axis, and eccentric, if object out-of-line of system. Disk performs in this case the role of modulator and sensing element. During the eccentric shift of the circle/circumference of the rotation of object changes the signal frequency, by which is determined the shift of object [45].

As the example of the servo photoelectronic device/equipment, in which the process of tracking is conducted due to the use/application of original trajectories of scanning, it is possible to examine the device/equipment, represented in Fig. 19. In it is used the

photoelectric dissector, which realizes cross-shaped scanning/sweep of controllable/controlled/inspected field [47]. With the aid of the deflection coils, supplied by the current, which has laws governing the change with time in the form of triangle (with a frequency of 400 Hz) (Fig. 19c), is conducted the photoelectronic scanning/sweep of image in the form of cross. With the coincidence of the image of object with the center of the input screen of dissector (Fig. 19a) the formed/shaped signal takes the form, represented in Fig. 19d. In this case all output pulses have an identical duration and follow each other in pairs with a frequency of 800 Hz.

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If the image of object is displaced relative to the axis of system, for example to the right (Fig. 19b), then two impulses/momenta/pulses in the right side of the scanning/sweep will have smaller duration than in the left (Fig. 19d). Because of this in the output signal there appears the component of fundamental sweep frequency (400 Hz), which is the "error signal". In form of the obtained signal (in comparison with the supporting/reference) it is possible to judge value and direction of the shift of object relative to the optical axis of servo system.

Developed by the author is a number of new photoelectronic

devices/equipment which can be divided into two groups:

1) the devices/equipment, in which for the formation of the error signal is conducted the separation of the luminous flux with the subsequent commutation or the obturation of the corresponding photoelectronic flows;

2) device/equipment with different types of the trajectories of scanning the region of field on which is arranged/located the object of tracking.

Let us examine the first group of followers.

The operating principle of the servo photoelectronic device/equipment with divided luminous fluxes [51], represented in Fig. 20, is reduced to the following. With the aid of objective 1 radiations/emissions from the object are directed to tetrahedral mirror pyramid 2, after being reflected from faces of which and from mirrors 3 they fall into zones A, B, C and D of the input screen of scanning dissector 4. The parameters of device/equipment are selected so that if the image of the radiating object is arranged/located on the optical axis of servo systems, all four faces of mirror pyramid enter identical luminous fluxes. In this case in all zones A, B, C, D of the input screen of the dissector the illumination is identical.

If object is displaced relative to the optical axis of servo system, then to different faces of mirror pyramid fall the luminous fluxes of different intensity, and in zones A, B, C, D illumination different.

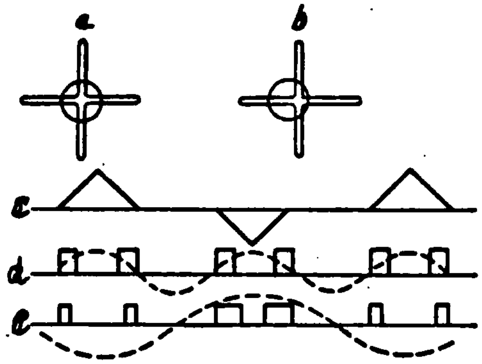

Fig. 19. Operating principle of the photoelectric follower with the cross-shaped trajectory of scanning and signal aspect (b, c, d).

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In this case it will be more in that zone in direction of which was displaced the object.

In order to form the electrical signal in form of which it would be possible to judge the direction of the shift of object, is realized scanning the photoelectric screen of dissector. For this on the dissector is arranged/located deflection system 5.

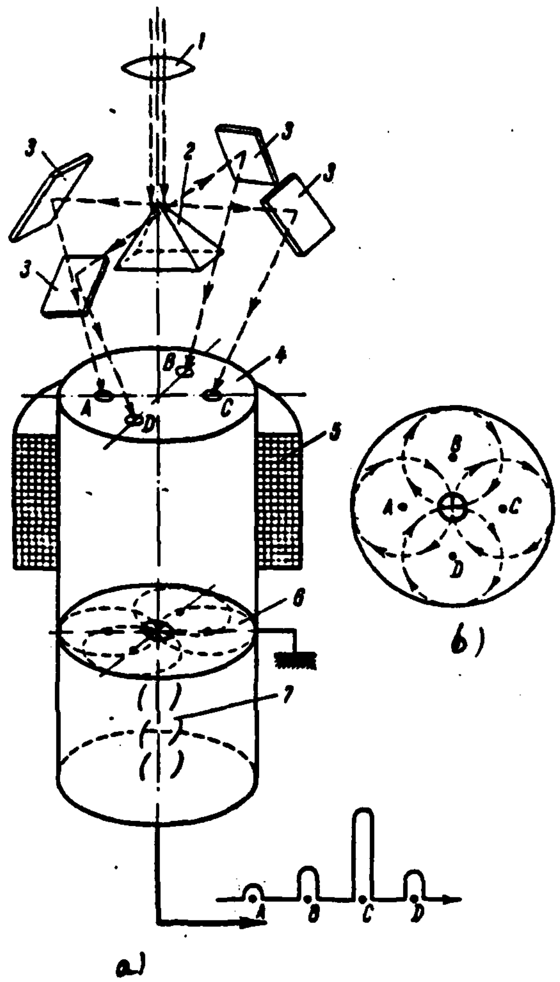

Fig. 20. Photoelectronic follower with the divided luminous fluxes and the commutationof photoelectronic flows.

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To the deflection coils are supplied the sine voltages, which have identical ones frequency and amplitude, but out of phase on 90°. In this case is created the rotating magnetic field under action of which the point of electron image, located in the center of the input screen of dissector, is moved in the circle/circumference on the diaphragm of 6 dissectors, which has central opening/aperture. In this case all remaining points of the electron image, designed on the input screen of dissector, also complete motion along the circle. During the appropriate selection of the amplitudes of the sine voltages, supplied to the deflection system of dissector, occurs this rotary displacement of electron image, that into the opening/aperture of the diaphragm of dissector alternately fall the photoelectronic flows from zones A, B, C, D. After traversing the opening/aperture of the diaphragm of dissector, photoelectronic flows fall on electron multiplier 7. Thus is conducted the sequential scanning of zones A, B, C and D. Via the

comparison of the form of the signal obtained from the dissector with the reference signal as which can be used the stresses/voltages, supplied to the deflection system, is determined the direction of the shift of object. Error signal thus found is supplied to the actuating elements which combine the optical axis of servo system with the direction to the object.

The second photoelectronic follower, developed in IAT [52], has the following schematic diagram (Fig. 21). As in the previously device/equipment examined, radiations/emissions from the source, after which is realized the tracking, by objective 1 are directed to the apex/vertex of tetrahedral mirror pyramid 2, from which with the aid of four mirrors 3 they are supplied on the input screen of special dissector. The latter is made on the usual diagram, but its diaphragm 5 is equipped with four figure windows. Each window is circle with the nine times sector gashes. The centers of windows are arranged/located on the diaphragm symmetrically through 90°. After the windows which occupy only certain part of the diaphragm, is established/installed one general/common/total for all windows electron multiplier. Thus, the photoelectronic flows, which fall into each window, are added then in electron multiplier. Dissector is equipped with deflection system 4, to coils of which are supplied two sine voltages of the identical ones of amplitude and frequency, but dephased by 90°. Thus is created the rotating magnetic field which

forces each point of electron image (formed/shaped on the photoelectric cathode dissector under the action of optical image) to complete rotary motion along the circle/circumference. In view of the fact that occurs the synchronous rotary motion of all four divided images of object, the figure of sector modulator in each window is turned relative to the figure of the modulator of adjacent windows on 90° (all figures having identical form).

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The operating principle of this device/equipment is reduced to the following. If the object is arranged/located on the optical axis of servo system, then from four mirror faces of pyramid 2 and four mirrors 3 into zones A, B, C and D of the photoelectric cathode of dissector fall the luminous fluxes of equal intensity. In accordance with these zones of the photoelectric cathode of dissector imitate the photoelectronic flows of the equal intensity with which with the aid of deflection system 4 are given the rotary motion along the windows of diaphragm 5. The trajectories of the motion of these flows along the windows of the diaphragm of dissector, which have the form of circle/circumference, they are shown by dotted line.

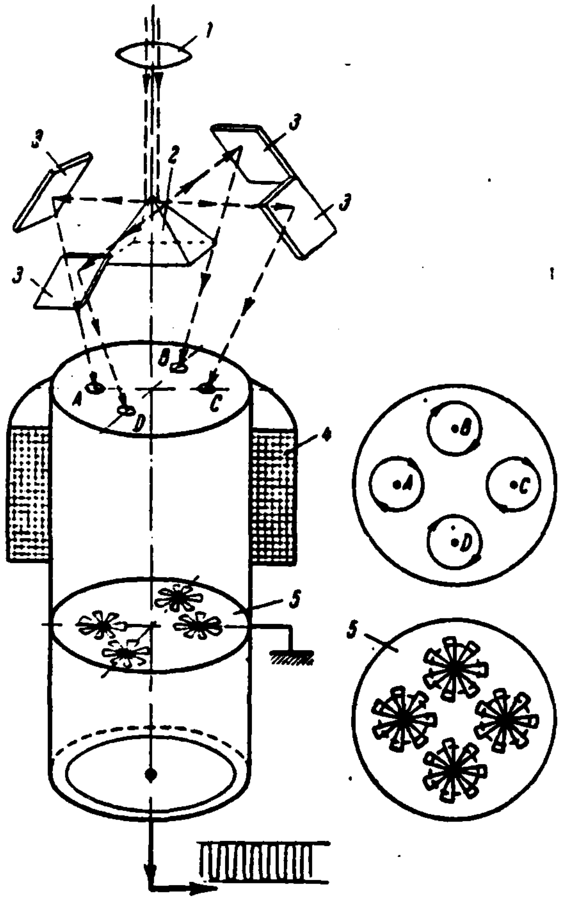

Fig. 21. Photoelectronic follower with the divided luminous fluxes and the obturation of photoelectronic flows.

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In view of the fact that the intensity of all four photoelectronic flows is identical, modulations of total signal does not occur. This is the consequence of the fact that during the synchronous rotation

of four images of object (having equal illumination) on the modulating windows each of which has nine sector gashes and figures of which they are turned relative to each other on 90°, the total number of photoelectrons, which fall on the anode, is equal at any moment of time. If object is displaced from the optical axis of servo system, then the luminous flux, which goes from that face of the mirror pyramid in direction of which is displaced the object, there will be more than the luminous fluxes, which go from its remaining faces. After being reflected from mirrors 3, the luminous fluxes of different intensity fall into zones A, B, C, and D of photoelectric cathode, moreover greater intensity of illumination will have that zone in direction of which is displaced the object. Further, the photoelectronic flows, which go from these zones, with the aid of the deflection system complete rotary displacements over the circular paths on the windows of diaphragm. The centers of these trajectories coincide with the centers of the circular sector windows of diaphragm. In this case, as a result of the fact that the intensity of the luminous fluxes is different, the total signal of dissector will be modulated by the specific frequency. Modulation frequency is determined by a number of gashes in the sector modulators and by the angular rate of rotation of photoelectronic image. The phase of the obtained signal depends on the direction of bias/displacement. Phase shift is determined in the special block/module/unit via comparison with the reference signal as which can be used the stress/voltage,

supplied to the deflection system of dissector. Error signals obtained thus can be given to the actuating element which will combine the optical axis of the servo system with the direction to the object.

The major advantages of the device/equipment examined, are its simplicity, reliability, small overall sizes and weight.

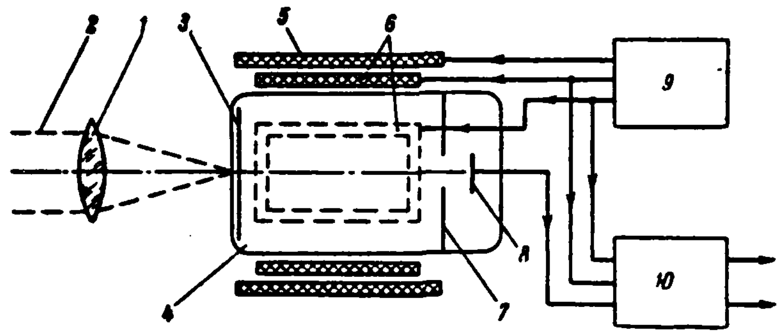

Fig. 22. Overall structural diagram of the photoelectronic servo scanning devices/equipment.

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Let us switch over to the second group of the photoelectronic followers, developed in IAT and acting without the separation of the luminous flux. Will examine certain generalized pattern of the follower of the second group and its those nodes/units, which to a sufficient degree are general/common/total for all given below photoelectronic followers (Fig. 22). By optical system 1 of radiation/emission of 2 units they are focused on the surface of the photoelectric cathode of 3 dissectors 4. The flow of photoelectrons emergent under the effect of radiation/emission is forwarded toward anode 8 (or to the first emitter of electron multiplier). Coil 5 by its magnetic field focuses the electron image of object in the aperture plane of 7 dissectors. To two identical pairs of coils 6,

arranged/located so that their magnetic fields deflect/divert electrons in the mutually perpendicular directions, are supplied deflecting voltages from the power supply unit by 9.

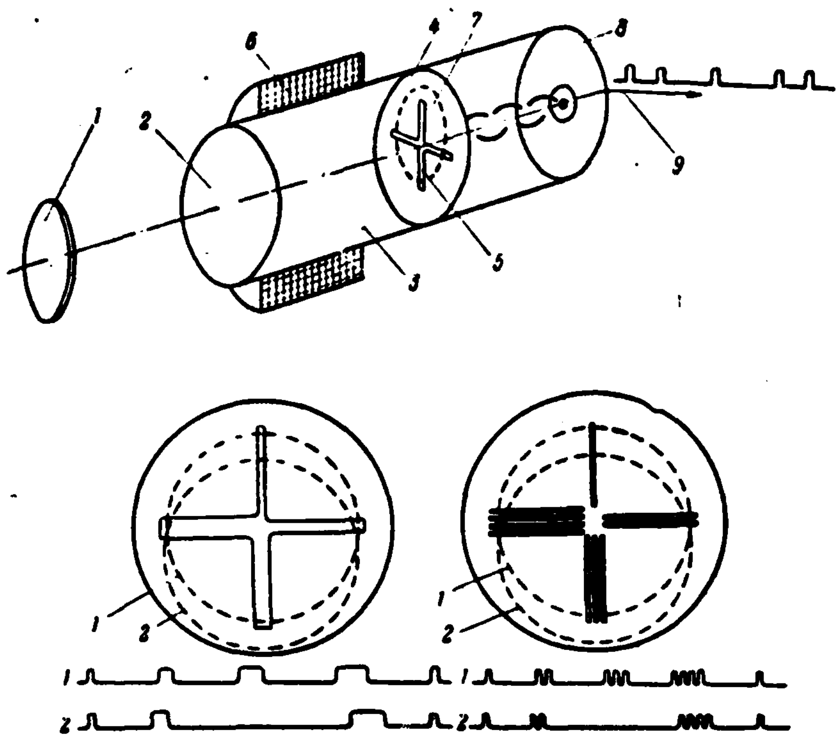

Fig. 23. Photoelectronic scanning device/equipment with the cross-shaped opening/aperture in the diaphragm of dissector.

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Under the action of the magnetic field of these coils electronic spot is moved in the aperture plane, moreover the trajectory of displacement is determined by change in the time of deflecting voltages. The obtained from the dissector signal is compared in converter 10 with the reference signals (by them serve the stresses/voltages, which feed deflection coils), as a result of which

are developed the error signals of the axis of optical system relative to direction to the object in two mutually perpendicular directions.

These signals control motors, moving entire system to the position in which the image of object lies/rests on the optical axis of system.

The author developed the photoelectronic scanning device/equipment with the cross-shaped opening/aperture in the diaphragm of dissector and the circular path of scanning [53]. The operating principle of this device/equipment is reduced to the following (Fig. 23). Radiations/emissions from object with optical system 1 are projected/designed for the photoelectric cathode of 2 dissectors 3. Under the effect of radiations/emissions the flows of photoelectrons are fixed to the anode, but the majority of them is detained by diaphragm 4, which has cross-shaped opening/aperture 5. By deflection system 6 is created the magnetic field, which rotates the flow of photoelectrons. In this case the electron image of radiation source is moved on the diaphragm along the trajectory, which has the form of circle/circumference. The amplitudes of the stresses/voltages, supplied to the deflection system, are selected by such that the diameter of a circle, in which is moved the center of electronic spot, would be somewhat less than the diameter of a

circle, into which is entered cross-shaped aperture of diaphragm. If radiation source is located on the axis of optical system, then the circle/circumference, in which is moved its electron image, it is true with the center of diaphragm. In this case from the dissector is removed/taken the pulse signal, in which the impulses/momenta/pulses follow through the equal time intervals. With the divergence of the image of radiation source from the optical axis of system the circle/circumference, in which is moved its electron image, it becomes eccentric with the center diaphragm. In this case photoelectronic flows fall on the anode with the passage of the electron image of object, for example, only along three sides of cross-shaped opening/aperture. In this case in the sequence of the impulses/momenta/pulses, which go from the dissector, will be absent each fourth impulse/momentum/pulse. Comparing the obtained signal with the supporting/reference (supplied to that deflecting of systems(, it is possible to determine the direction of the bias/displacement of object.

For the simplification the operations/processes of determining the direction of the shift of the side of cross-shaped gash can be made different width or consisting of several slots. For example, the first gash of one slot, the second of two, etc. In this case the signal will consist of the bursts of pulses.

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On absence of one or two of the bursts of pulses it is possible to unambiguously determine the direction of the shift of object.

This dissector can be made four-channel, when each side of cross-shaped gash will have its separate electron multiplier. Then is possible its inclusion into the differential circuit.

The author together with Yu. V. Strelnikov developed the photoelectronic follower in which the diaphragm of dissector has the circular opening/aperture, true with the axis of dissector and with the optical axis of system, and is used the trajectory of scanning in circle/circumference [54]. The operating principle of device/equipment is reduced to the following (Fig. 24). To the deflection coils from the stabilized source of alternating current are supplied the sine voltages; U_y - to the pair of the coils, which deflect electrons along the axis y, and U_x - to the pair of the coils, which deflect electrons along the axis x (Fig. 24). These stresses/voltages have an identical frequency and an amplitude, but they are out of phase on 90°. In this case is created the rotating magnetic field under action of which the spot of the electron image of object is moved in the aperture plane in the circle/circumference. The amplitudes of stresses/voltages are selected by such, that the

diameter of a circle, in which is moved the center of electronic spot, is equal to the diameter of the opening/aperture of diaphragm. If radiation source is located on the optical axis of system, then the circle/circumference, in which is moved the electron spot, it is true with the opening/aperture of diaphragm. In this case from the dissector is removed/taken certain steady signal which does not pass through the amplifier circuit. With the divergence of the image of radiation source from the optical axis this circle/circumference becomes the eccentric with the opening/aperture diaphragm of dissector, and in its signal appears variable component.

For example, with the divergence of source image along the axis x to point O_1 electronic spot rotates in circle/circumference 1. In this case from the dissector is removed/taken the pulse signal U_1 (Fig. 25). With the divergence of image along the axis y to point O_2 electronic spot rotates in circle/circumference 2, and from the dissector is removed/taken signal U_2. The signal intensive in the preamplifier from the dissector enters the selective amplifier, in which is isolated its fundamental harmonic.

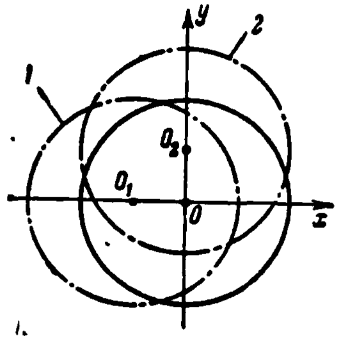

Fig. 24. Position of the trajectories of scanning relative to circular opening/aperture in the diaphragm of dissector in the presence of the disagreement/mismatch between the optical axis of system and the direction to the object.

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Its amplitude-phase characteristics are determined by the resolution of pulse signal in the Fourier series:

$$f_1 = F_1 \cos(\omega t - \psi_1),$$

where f_1 - instantaneous value of the stress/voltage of the fundamental harmonic; F_1 - amplitude; ω - the angular frequency of the fundamental harmonic, equal to the angular frequency of deflecting voltages; ψ_1 - initial phase of the fundamental harmonic.

Fig. 25 shows fundamental harmonics f_{1_1}, and f_{2_1}, which correspond to the pulse signals U_1 and U_2.

The determination of the shift of radiation source relative to optical axis from two mutually perpendicular directions x and y is conducted in two devices/equipment via the comparison of the fundamental harmonic of the signal of dissector with appropriate deflecting voltages U_x and U_y. As such devices/equipment can be used the phase-sensitive rectifiers (full-wave demodulators).

In the case of applying the two-phase mastering engines it is possible to manage without phase-sensitive devices in the electronic circuit. On the first windings of engines must be supplied reference voltages U_x and U_y, moreover stress/voltage U_x must be supplied to the first, and stress/voltage U_y on the second engine. To the second windings of engines must be supplied the intensive fundamental harmonic of signal from the dissector. Engine in this case combines in itself the functions of phase-sensitive and resetters.

The author together with Yu. V. Strelnikov and R. N. Blaut-Blachevy developed the follower in which in diaphragm dissector made square opening/aperture is used the trajectory of scanning in the form of square [55]. The square opening/aperture of diaphragm is the grid, the width of metallic strips of which is equal to the diameter of the electron image obtained on the diaphragm of radiation

source (Fig. 26). Grid is made in such a way that its diagonals are arranged/located along the axes x and y, which coincide with the direction of the magnetic field of deflection coils. To the latter from the power supply unit are fed stresses/voltages U_x and U_y of symmetrical triangular form, identical frequency and amplitude, but out of phase on 90° (Fig. 27).

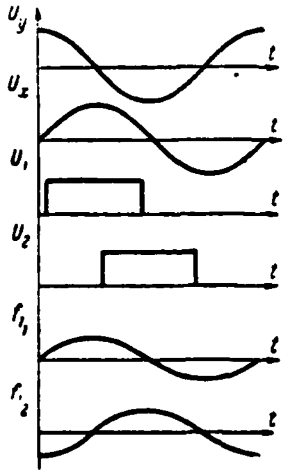

Fig. 25. Signal aspect in the photoelectronic follower with the circular opening/aperture in the diaphragm of dissector and the circular trajectory of scanning.

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If radiation source is combined with the optical axis of system, then electronic spot is arranged/located in center O_1 of grid. During application to the deflecting pressure coils of the required value the image is moved in the aperture plane along the square trajectory along the edges of grid, as shown by broken line in Fig. 26. From dissector in this case is removed/taken the continuous pulse signal U_1 (Fig. 27). With deviation of the optical axis of system from the direction to the radiation source the square trajectory, along which is moved electronic spot, is displaced relative to grid. Pulse signal

in this case it proves to be that modulated with the voltage frequency, applied to the deflection coils.

Fig. 26 depicts three trajectories of the electronic spot, obtained during the shift of the image of object into points O_2, O_3, O_4, while in Fig. 27 the corresponding to them signals U_2, U_3, U_4, taken from the dissector.

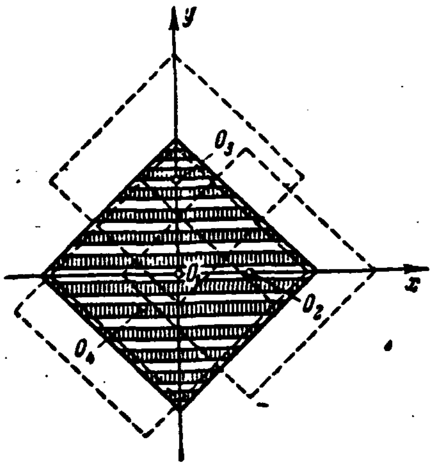

Fig. 26.

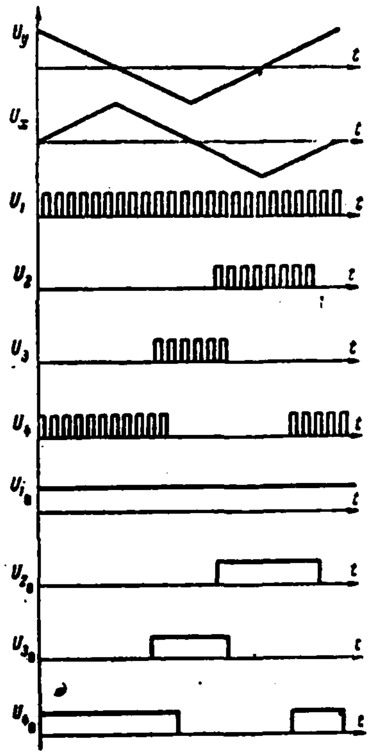

Fig. 27.

Fig. 26. Position of square trajectories of scanning relative to square modulating grid in presence of disagreement/mismatch.

Fig. 27. Signal aspect of photoelectronic follower in diaphragm of which is made square opening/aperture with modulating bands.

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Signals from the dissector are amplified by preamplifier and selective amplifier, tuned to the frequency with which is interrupted/broken by grid the electron stream, which enter the anode. Then signals are detected in the detector. Obtained after envelope detector U_1, U_2, U_3, U_4 are compared with respect to the phase to phase by supporting/reference voltages U_x and U_y in two phase-sensitive blocks/modules/units. As a result of comparison are developed the error signals of the optical axis of system from the direction to the radiation source along the axes x and y.

Use/application in the schematic of square grid examined with the narrow bands makes it possible to substantially restrict the effect of the background of sky and to raise signal-to-noise ratio and, consequently, also the accuracy of tracking the radiation source. By the use/application of selective amplifiers in both devices/equipment is achieved the limitation of the inherent noise of dissector and electronic circuit.

The author together with Yu. V. Strelnikov and R. N. Blaut-Blachevy developed the photoelectronic follower, in which to the deflection coils are supplied two sine voltages with the different frequencies: stress/voltage U_x with a frequency of ω_1 on one pair of coils and stress/voltage U_y with a frequency of ω_2 to another pair of coils [56]. The diaphragm of dissector has the square

opening/aperture whose center is arranged/located on the axis of dissector (Fig. 28). During simultaneous feed of both deflecting voltages occurs the double modulation of the output signal of dissector. Let us examine first the form of output signal during the application of stress/voltage only to one pair of the deflection coils whose magnetic field displaces electron stream in the horizontal direction.

Fig. 29a shows voltage U_x, applied to the coils, which realize horizontal deflection of electron stream. It is accepted that to an increase in the stress/voltage in the positive direction corresponds the shift of electronic spot to the right (Fig. 28). The value of stress/voltage is selected by such that the amplitude of shift C would be more than half of free transmission range: C>d/2. But exaggerated amplitude to select one ought not, since in this case increases the porosity of impulses/momenta/pulses and decreases output signal. Let us accept the amplitude of shift to equal free transmission range C=d, that it does not disrupt the generality of reasonings.

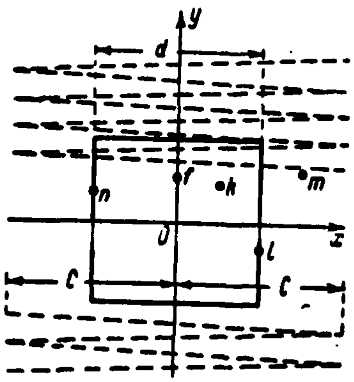

Fig. 28. Parameters of the servo photoelectronic device/equipment with the square opening/aperture in the diaphragm of dissector.

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Let us assume that the image of object does not have a shift in the horizontal direction and its center is located at point on axis y (see Fig. 28). In this case from the dissector is removed/taken the pulse signal U_1 (Fig. 29b), symmetrical relative to the axis of ordinates. By resolution in the Fourier series it is easy to ascertain that the envelope of impulses/momenta/pulses contains only the even harmonics of fundamental frequency ω_1 (in Fig. 29b broken line depicted second harmonic $a_{2_1}\cos 2\omega_1 t$). During the shift of the image of object from y axis to the right into point k from the dissector is removed/taken signal U_2 (Fig. 29c). The envelope of impulses/momenta/pulses in this case takes the form of the asymmetric curve which contains harmonic $b_{1_1}\sin\omega_1 t$ of fundamental frequency. This harmonic has a phase, shifted on 180° with respect to the phase of stress/voltage U_x, supplied to the coils.

Fig. 29c, d presents two additional pulse signals U_3 and U_4, obtained with the divergence of the image of object respectively to the points l and m, and the fundamental harmonics of these signals

$b_{1s} \sin \omega_1 t$ and sin ω_1t. The amplitudes of these harmonics somewhat change, but phase displacement relative to voltage U_x remains constant/invariable and equal to 180°.

With the divergence of the image of object from the vertical axis to the left, into point n, from the dissector is removed/taken signal U_s (Fig. 29f). The phase of fundamental harmonic $_1 \sin \omega_1 t$ in this case coincides with the phase of stress/voltage U_x and to the antiphase of the signal, obtained during the shift of image to the right.

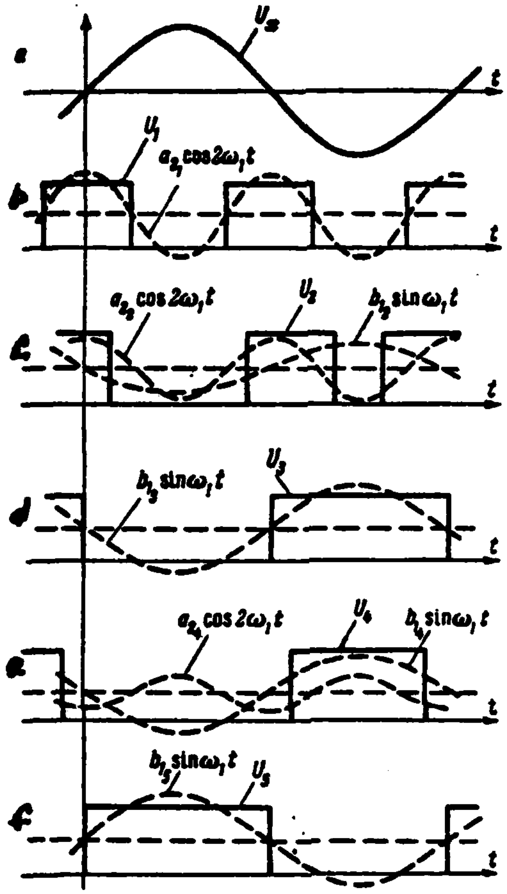

Fig. 29. Signal aspect of the photoelectronic follower with the line-by-line trajectory of scanning and the square opening/aperture in the diaphragm.

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In general form the signal, obtained from the dissector during the application of stress/voltage U_x to the horizontal deflection

coils, can be represented by the expression

$$f(x, t) = a_0(x) + b_1(x)\sin\omega_1 t + a_2(x)\ \cos 2\omega_1 t + \ldots,$$

where x - shift of the image of object on the diaphragm of dissector b horizontal direction.

In exactly the same manner, if we apply only voltage U_y with a frequency of ω_2 to the coils, which generate vertical deflection, then the obtained signal can be represented in the form:

$$f(y, t) = a_0(y) + b_1(y)\ \sin\omega_2 t + b_2(y)\ \cos 2\omega_2 t + \ldots,$$

where y - shift of the image of object on the diaphragm of dissector in the vertical direction.

During the simultaneous application of two deflecting magnetic fields occurs the multiplication of series/rows. Signal obtained in this case is the function of time and two coordinates of position of electronic spot on diaphragm x and y:

$$f(x, y, t) = a_0(x)a_0(y) + a_0(y)b_1(x)\sin\omega_1 t + a_0(y)a_2(x)\cos 2\omega_1 t + \\ + a_0(x)b_1(y)\sin\omega_2 t + a_0(x)a_2(y)\cos 2\omega_2 t + \ldots +$$

terms with the summation and difference frequencies.

The presence in resolution of harmonics with fundamental frequencies of ω_1 and ω_2 testifies about the divergence of the image of object relative to optical axis respectively with respect to the coordinate x and y axes (as it was shown above, during the

determination of the image of object on the optical axis in the output signal are present only the even harmonics of fundamental frequencies).

The signal from the dissector, intensified by preamplifier, enters two selective servo-amplifiers, adjusted respectively for the frequencies ω_1 and ω_2. Then harmonics with frequencies of ω_1 and ω_2 are compared in the demodulators on the phase with two reference voltages as which serve stresses/voltages U_x and U_y, feeding deflection coils. On phase displacement (0° or 180°) is determined the direction of the divergence of the image of object relative to the optical axis of system.

From the operating principle of device/equipment it is clear that the frequencies ω_1 and ω_2 must be selected so that they would not be the wholes, multiple to each other by numbers. Furthermore, servo-amplifiers must be designed in such a way that the components of signal with the summation and difference frequencies would be located out of the band of their transmission. If opening/aperture in the diaphragm takes the form not square, but rectangle, then in this case the amplitudes of deflecting voltages must be selected different from each other.

The important positive special feature/peculiarity of

device/equipment is the fact that the principle used in it of the determination of the disagreement/mismatch between the axis of optical system and the direction to the radiation source does not depend on phase displacement between two stresses/voltages U_x and U_y, which feed deflection coils, and allows/assumes without a reduction in the accuracy the considerable amplitude oscillations of deflecting voltages.

The limitations, superimposed on frequency stability ω_1 and ω_2 of deflecting voltages, also are not very strict. Signal-to-noise ratio in the device/equipment is increased, since are utilized selective amplifiers.

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Chapter 9.

SERVO DEVICES WITH THE COMPLEX OF PHOTORESISTORS.

As it was already noted, followers can be conditionally broken into two groups. The first compose the optical-mechanical and photoelectronic devices/equipment with the use of scanning the small region of field in which is located the object, with the aid of different elementary trajectories. To deficiencies/lacks in such devices/equipment one should relate the complexity of construction/design, large weight and considerable overall sizes. Furthermore, the use of the rotating or moving elements/cells during the mechanical scanning, and also high voltages and the stresses/voltages of special form during the electronic scanning decreases the reliability of the work of entire device/equipment.

The second group compose the devices/equipment in which for determining the error angle the luminous flux from the object of radiation/emission is directed to several sensing elements symmetrically arranged/located relative to optical axis. In the followers of this group, in contrast to preceding/previous obtaining

information about the shift of object occurs not as a result of image drifts of object (optical or photoelectronic) relative to modulating grids and sensing elements, but as a result of the differential perception of changes in the luminous energy, which falls on the complex of photoresistors during the shift of the image of object. These devices/equipment are deprived of the deficiencies/lacks, inherent in the devices/equipment, which realize photoelectronic or optical-mechanical scanning, but have their, from which basic is certain difference in the electrical characteristics of sensing elements, which introduces the specific error.

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Let us examine several devices/equipment of this group. For the tracking of the position of the object, focused in the form of circle, can be used the devices/equipment in which the tracking is realized by changing illuminating the planes of the series/row of sensing elements for which simultaneously is projected/designed the image of object. As a schematic example let us examine device/equipment [48], represented in Fig. 30. The detector of the device consists of three silicon photocells. Optical system projects/designs the image of the circular object (not point) to detectors, the field of the view of each of which composes 90° from the center of the image of object. In the case, when the areas of

image, arranged/located on each sensing element, are different, and also, therefore, the illuminations of three detectors are equal, the axis of system directed to the center of object. During the shift of the image of object, i.e., with a decrease of the illuminated area on one detector and an increase on other, the determined and compared signals from the photocells establish/install the error signal. The latter acts on the electromechanical system which removes this disagreement/mismatch. Since the characteristics of separate photocells change differently, in the dependence on the temperature and in the course of time, in this system is provided the device/equipment, which realizes continuous calibration of photocells relative to each other. Neon flashbulb evenly illuminates each photocell. In this case on them is formed/shaped the signal, which consists of the constant and the variable/alternating of components. Constant component appears from the radiations/emissions of the unit, after which is realized the tracking, and variable/alternating - from the calibration lamp. With the identity of the characteristics of all elements/cells the amplitudes of variable components are identical. In two channels of diagram occurs the comparison of the amplitude of variable/alternating signal with its value, which occurs in the third channel. Depending on the relationships/ratios of these signals is introduced the corrective effect on the factor of amplification of channel, so that the factors of amplification of all three channels (taking into account the sensitivity of photocells) would be

identical.

Fig. 31 depicts the device/equipment of this class in which the image drifts along each axis are determined with respect to a change in the relationship/ratio of signals from two photocells.

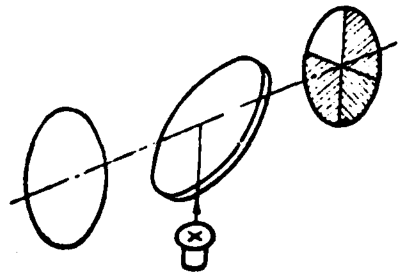

Fig. 30. Follower with three photocells, arranged/located in the circle/circumference, and by neon calibration tube/lamp.

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For the tracking along x and y axes are two channels which are identical according to the operating principle. Each channel has photocells rectangular 4 and triangular 3 forms for which by cylindrical lens 1 and with semitransparent mirror 2 is projected/designed the image of object, focused in the form of line. The output signals of the photocell of triangular form change in the dependence on the relative attitude of the line of image, created by cylindrical optic/optics. The output signal of rectangular photocell remains constant, without depending on the position of the image of object. The relation of signals from the triangular and rectangular photocells shows a change in the position of object relative to the axis of system. In this system also there is a device/equipment of calibration the operating principle of which is analogous examined

above.

To the same group there can be referred servo device, in which are utilized four identical photocells, placed in the plane, perpendicular to the optical axis of system [48]. Photocells are connected with the appropriate scaling circuit which makes it possible to automatically determine the shift of image from the optical axis of system. If object is arranged/located on the axis, then all four photocells are illuminated equally, and the error signal in the diagram it does not appear. If object is displaced from the optical axis, then by the values of the signals, which enter from the photocells, are determined value and direction of the shift of object relative to the optical axis of system.

Work [49] examines the device/equipment of a similar operating principle. In it four photocells are connected into the measuring circuit in such a way that with their aid is possible to follow any displacements of object. Work gives the diagrams of blocks/modules/units and the fundamental system characteristics.

This group of the scanning servo devices/equipment includes the devices/equipment in which the image of object is projected/designed for the set of the sensors, connected with the commutator. Here can be realized the time sharing of signals from different point sensors

or the frequency division multiplex of signals during their simultaneous transmission. As an example examined below the device/equipment, in which the tracking the displacement of object is realized with the aid of the complex of the sensors each of which is supplied by the alternating voltage of their frequency.

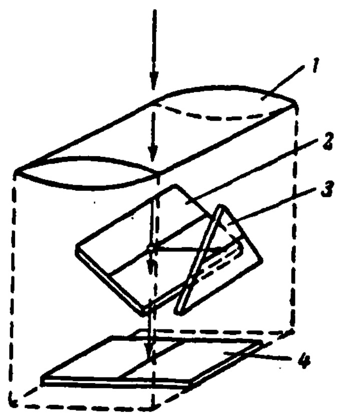

Fig. 31. Schematic diagram of one channel of follower with the square and triangular sensing elements/cells.

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The operating principle of this device/equipment is reduced to the following [57]. Sensing element is the series/row of the bolometer detectors, arranged/located in the manner that it is shown in Fig. 32. Sensing element 1 is placed in the focus of concave mirror 2. The circuit diagram of one bolometer detector is represented in Fig. 32c. Sensor consists of two bolometric plates A and B, connected with bridge circuit. To one of the plates (A) fall the radiations/emissions of unit, while another (B) it is shielded from it. Because of this during irradiation of sensor occurs the imbalance of bridge circuit. In all in four quadrants of sensing element are arranged/located sixteen bolometer detectors each of

which is supplied variable/alternating by the current of the specific frequency. To each sensor is supplied the alternating voltage from the master generator through multivibrator and filters of the corresponding frequencies. Signals from the sensors enter the mixer, and then into the amplifier circuit. In the latter there is a selector, which selects for further amplification signal from the sensor with the greatest amplitude. In this case output signal will have a frequency of the supply of that bolometer detector on which at the given moment/torque is found the image of object.

With the aid of this system in the frequency of output signal it is possible to determine the location of the image of object on the complex of sensors, and therefore to establish/install direction and value of the effect, necessary for the coincidence of the optical axis of system with the direction to the object. An essential deficiency/lack in the device/equipment examined is the complexity of diagram.

The author together with V. D. Zotov developed the photoelectric follower in which the useful signal, taken from sensing elements, does not depend on their electrical characteristics [58]. The schematic of this device/equipment is given in Fig. 33.

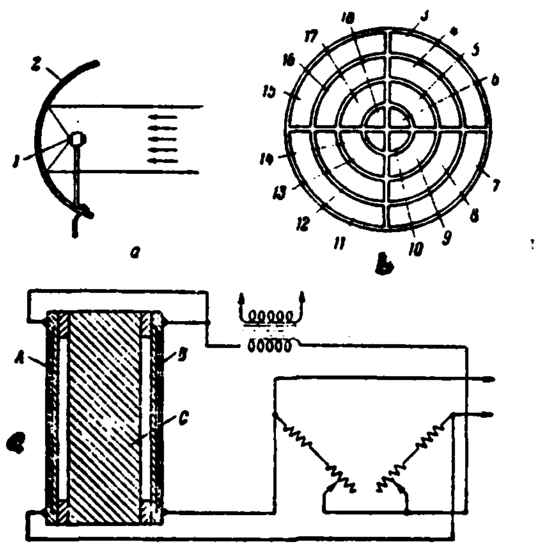

Fig. 32. The schematic diagram of follower, in which the image of object is moved on the complex of semiconductor sensors.

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The radiations/emissions of unit by optical system 1 I am directed to semitransparent mirror 2, arranged/located at angle of 45° to the optical axis of system. The part of luminous energy, after passing mirror, falls on photoresistor 3 (being sensing element of the axis of abscissas), another part is reflected to photoresistor 4 (being sensing element of the axis of ordinates). As sensing elements are used comb type differential photoresistors, which consist of the series/row of the alternating bands of elementary photoresistors and

narrow metallic collector strips. For this purpose, for example, can be used photoresistor FS-K76, subjected of the insignificant alteration: after the interruption/discontinuity of the connections of contact rack/comb it is the set of four elementary resistances, been connected in series (Fig. 34).

If we arrange one of such photoresistors by central contact along x axis, and another - along axis y (Fig. 35), then on the illumination of elementary resistances it is possible to determine the region of the location of the object of radiation/emission in the rectangular coordinate system. As can be seen from Fig. 35, in this case for each of the x and y axes are four levels of the position of the object of radiation/emission - two in the positive region and two in the negative.

The signals taken from the photoresistors enter the schematics of the isolation/liberation of position level on the basis of x and y (see Fig. 33, 5 and 6). In accordance with the position of the object each of the schematics of the isolation/liberation of level develops one of five possible signals: $U=0$; $U_1>0$; $U_2>0$; $U_3<0$; $U_4<0$, moreover $|U_1|=|U_3|$; $|U_2|=|U_4|$ and $U_2>U_1$.

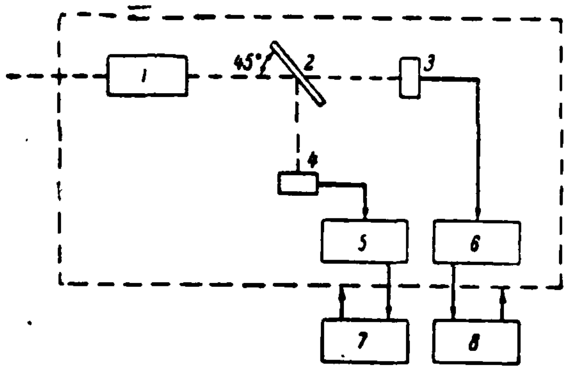

Fig. 33.

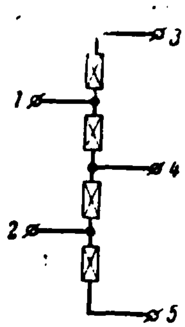

Fig. 34.

Fig. 33. Block diagram of follower with two differential photoresistors.

Fig. 34. Given diagram of differential photoresistor.

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The signals, given out by the schematics of the isolation/liberation of the level of the position of object, enter the control devices of the device/equipment of automatic tracking along the axes x and y (see Fig. 33, 7, 8).

Let us dismantle/select work of one of the channels of the schematic of the isolation/liberation of the level of the position of

the object (electrical circuits of the isolation/liberation of signal level on the basis of x and y are identical). In parallel to each of four elementary photoresistors of comb photoresistor is connected resonant circuit (Fig. 36). As the capacities/capacitances in circuits are used semiconductor diodes D_p, capacity/capacitance p - n-transfer of which can be changed depending on the applied to them stress/voltage, for example diodes D=808, D=811 and so forth. To each elementary photoresistor is given constant feeding stress U_n; furthermore, to the system of ducts/contours from the source of sinusoidal oscillations are applied the variable/alternating feeding voltages with frequencies of f_1 and f_2 ($f_2>f_1$).

In the absence of the object of radiation/emission the resonant circuits are in pairs tuned to frequencies f_1 and f_2. In this case to the near to the axis of level tube of position both in the positive and in the negative region corresponds frequency f_1, to distant levels - f_2. From secondary winding of each duct/contour is removed/taken the alternating voltage of the corresponding frequency. After amplification it enters rectifier D_1C_1 and then the diode comparison circuit. The cathode of diode D is connected to the divider of voltage R_1-R_2, to one entrance of which is given positive stress/voltage from the rectifier, and on another the negative reference voltage E. The anode of diode is connected to the resistance/resistor of load R_n, from part of which is removed/taken

exit voltage $U_{вых}=0$. Positive voltage from the rectifier in the amplitude exceeds the reference voltage E; therefore diode is closed and $U_{вых}=0$.

Let us assume that to one of the elementary photoresistors falls the flow of luminous energy. In this case the value of resistance is changed, which produces change in the control voltage, supplied to the reactive/jet diode. A change in the voltage on the diode, and their turn, produces change in capacity/capacitance of p - n-transfer. The resonance frequency of the circuit becomes different from the frequency of the feeding alternating voltage f_1 or f_2.

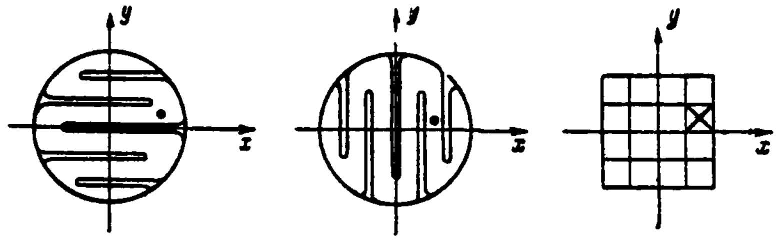

Fig. 35. Operating principle of follower with two differential ones to photoresistors.

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Because of this the secondary winding of duct/contour and respectively on the output of rectifier there is no stress/voltage or it is small. In this case diode D is opened/disclosed by negative reference voltage, along resistance $R_{\text{н}}$ flows the current of diode and $U_{\text{вых}} \neq 0$.

The polarity of exit stress/voltage $U_{\text{вых}}$ indicates, in what region (positive or negative) is located the object of radiation/emission, amplitude determines the amount of the shift of object.

Work [59] examines certain questions, connected with the error analysis in tracking of an object of radiation/emission with the aid

of this device/equipment. With the coincidence of the optical axis of system with the direction to the object the image of the latter will be located on the central contact strip of sensing element. In this case an error in tracking object in essence will be defined by the dead zone of device/equipment, which appears as the result of relationship/ratio (h/d), where d - diameter of luminescent spot or the side of square with the square spot, h - width of the central contact strip of photoresistor.

Let us examine three possible cases of relationship/ratio $\frac{d}{h}$.

1. With h>d width of dead zone

$$\delta = h - d + 2\Delta h,$$

where Δh - value of photosensitive layer of photoresistor, which must be lit for obtaining distinguishable signal (Fig. 37).

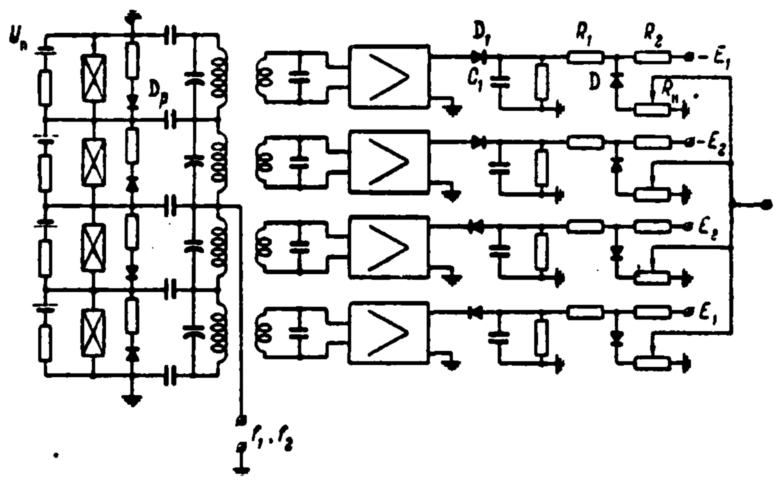

Fig. 36. Electrical circuit of follower with two differential photoresistors.

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The width of dead zone is defined as the extent of the movement of the center of luminescent spot over the radial deflection terminal, with which does not occur changes in the signal. If luminescent spot has a form of square with side d, then $\Delta h = S/d$, where S - area of the photosensitive surface of photoresistor, which must be lit for obtaining the minimally distinguishable signal.

Value S is found from the formula, which is determining the value of the photo current of resistance:

$$I_{\Phi} = k_0 LUS \cdot 10^{-4},$$

whence at given values I_Φ, k_0, L and U we have

$$S = \frac{I_\Phi}{K_0 L U \cdot 10^{-4}},$$

where I_Φ - minimally distinguishable photo current; k_0 - specific sensitivity of photoresistor; L - illumination of luminescent spot; U - feeding constant stress.

Thus, the width of dead zone

$$\delta = h - d + 2\frac{I_\Phi}{k_0 L d U \cdot 10^{-4}}.$$

2. With h=d width of dead zone decreases to value:

$$\delta = 2\frac{I_\Phi}{k_0 L d U \cdot 10^{-4}}.$$

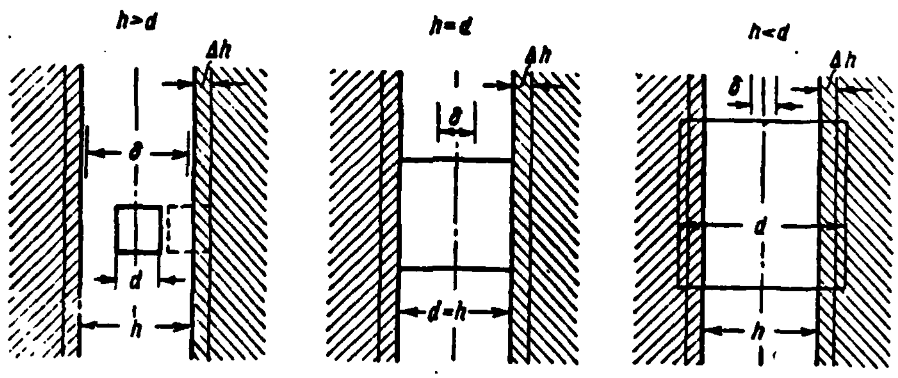

Fig. 37. Illustration to the accuracy analysis of follower with different relationships/ratios of image sizes of object and width of the collector strip of differential photoresistor.

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3. With h<d we have width of dead zone :

$$\delta = d - h - 2\frac{I_\Phi}{k_0 LdU \cdot 10^{-4}}.$$

Analogously is determined the width of dead zone with the luminescent spot, which has the form of circle [59].

1. With h>d width of dead zone is equal to:

$$\delta = h - d + 2\Delta h.$$

In the case of round luminescent spot value Δh is equal to the height/altitude of segment, which is located on the photosensitive surface of photoresistor and having the area, necessary for obtaining of the minimally distinguishable signal:

$$\Delta h = d \sin^2 \frac{S \cdot 90}{\pi d},$$

where S - area of segment.

After replacing S by the obtained above expression, we have:

$$\delta = h - d + 2d \sin^2 \cdot \frac{I_\Phi}{k_0 LU \cdot 10^{-4}} \cdot \frac{90}{\pi d}.$$

2. With h=d width of dead zone is equal to:

$$\delta = 2d\sin^2\frac{I_\Phi}{k_0 LU\cdot 10^{-4}}\cdot\frac{90}{\pi d}.$$

3. With h<d width of dead zone can be expressed as follows:

$$\delta = d - h - 2d\sin^2\frac{I_\Phi}{k_0 LU\cdot 10^{-4}}\cdot\frac{90}{\pi d}.$$

As, we see, for case of h<d upon reaching/achievement of the equality

$$d - h = 2\Delta h$$

the width of dead zone and, consequently, also error trackings vanish:

$$\delta = d - h - 2\Delta h = 0.$$

The maximum error in the tracking is with h>d.

The device/equipment examined has a number of essential advantages in comparison with other systems of this class:

1) simplicity of construction, the absence of moving elements/cells and complicated scanning devices/equipment, and also simplicity of electronic circuit, which provides the increased reliability of operation;

2) stability to the vibrations and the impact effects due to the absence of electron tubes, sliding contacts and the like;

3) the absence in the electronic circuit of high voltages and stresses/voltages of special form;

4) small overall sizes and weight.

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In the institute of automation and telemechanics is developed the laboratory sample/specimen of the schematic of the isolation/liberation of the level of the position of the object of radiation/emission, in which was used that examined above principle of action. Tests of diagram gave good results.

Chapter 10.

FOLLOWERS WITH THE ROTATING OPTICAL ELEMENTS/~~CELLS~~.

As it was already noted, there is a class of the servo optical-mechanical devices/equipment, in which with the aid of the rotating optical elements/cells is realized the rotation of the image of object relative to motionless sensing elements. This class, in particular, includes the devices/equipment with the rotating optical wedges and the rotating inclined mirrors. In such devices/equipment in the case of the location of object on the optical axis of system the image of object is described on the modulating disk of the circles/circumferences, true with its axis. In the case of shifting the object from the optical axis of system, the image of object is described on the modulating disk of the circles/circumferences, eccentric with its axis. On the signal obtained from the photocell it is represented possible to determine the disagreement/mismatch between the direction to the object and optical axis of system. Let us examine as an example several devices/equipment of this group.

The servo scanning device/equipment with the reflecting optic/optics is represented in Fig. 38. In it [60] the radiations/emissions from the object with the aid of concave mirror 4

are directed to flat/plane scanning mirror 2, rotated by electric motor 1 at a rate of 50 r/s, and further to modulating disk 3 with a radially-cross-hatched grid. Then radiations/emissions enter photomultiplier 5. During the shift of object from the optical axis of system its image crosses out on the modulating disk eccentric circles/circumferences, moreover eccentricity is proportional to the amplitude of the shift of object. For increasing the modulation frequency the modulator is made by that rotating and interrupts/breaks the luminous flux, which falls to the photomultiplier, with a frequency of about 2 kHz. Then signal is amplified, is limited, is compared with respect to the phase with the reference signal from the electric motor and is converted into the direct current, proportional to coordinates x and y. These signals control the hydraulic servodrives which combine the optical axis of system with the direction to the object.

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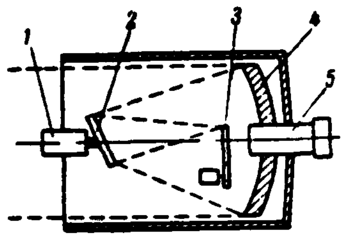
Fig. 39 presents the device/equipment in which for the rotation in the plane of the modulating disk, focused in the form of the image point of object, is used optical wedge [61]. After the modulating disk is arranged/located the photocell which enters the modulated luminous flux. After passage through rotating wedge 1 the luminous flux, reflected from concave mirror 2, is focused to modulating disk

3. If radiation source lies/rests on the optical axis of system, then luminescent spot describes on the modulating disk circle/circumference with the center on the optical axis of system. In this case on photocell fall the light impulses/momenta/pulses of equal duration. During the shift of the light source from the optical axis of system the image of object describes on the modulating disk the circle/circumference whose center is displaced relative to the optical axis of system, in this case the photocell enter the light impulses/momenta/pulses of different duration. This effect is utilized for determining of value and direction of the divergence of object from the optical axis.

In the class in question there is a group of the devices/equipment, in which the rotation of the image of object is realized with the aid of the rotating prism of the Doves. In these devices/equipment the radius of gyration of the image of the object, which passed through the prism, changes depending on the amount of the shift of object, moreover the angular rate of rotation of the image of object is two times more than the speed of rotation of prism itself. On the basis of the use of these properties of the Dove prism is developed a group of the servo scanning devices/equipment in which with the aid of comparatively simple diagrams can be defined both the direction and value of disagreement/mismatch.

Is examined below the group of such devices/equipment in which are used the in principle different circuits of photoelectric separation and analysis of light information, which enters from the rotating Dove prism.

Fig. 40 presents the servo system, in which modulation of the luminous flux is realized with the aid of the Dove prism and motionless modulating disk [62].



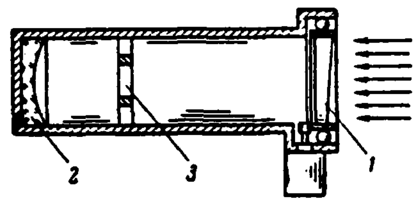


Fig. 38.

Fig. 39.

Fig. 38. Servo scanning device/equipment with rotating inclined mirror.

Fig. 39. Servo scanning device/equipment with rotating optical wedge.

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In this case, when object is arranged/located on the optical axis of system, its image is arranged/located in the center of the modulating disk. In this case modulation in the signal of photocell is absent. During the shift of object from the optical axis of system the image of object describes on the modulating disk concentric circles/circumferences. On the phase of the signal obtained from the photocell is determined the direction of the shift of object relative to the optical axis of system. For the comparison is utilized the signal from the reference oscillator. The windows, situated on the periphery of disk, are intended for the rough tracking when occur the

divergences of high value.

Let us examine the follower in which the image rotates with the aid of the Dove prism and simultaneously rotary motion completes modulating disk [63].

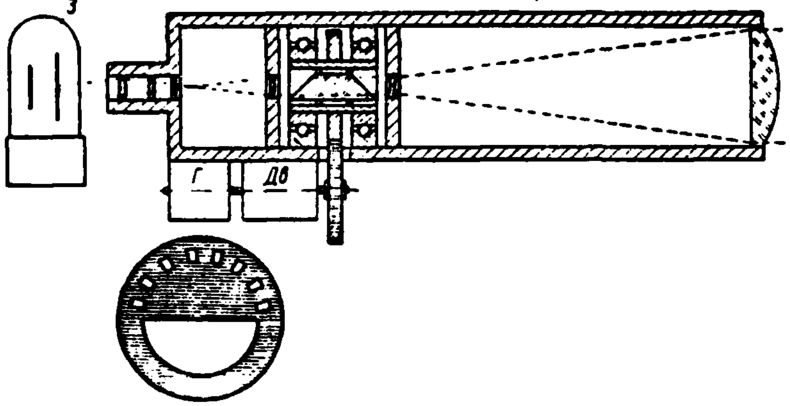

Fig. 40. Follower with rotating Dove prism and motionless semidisk.

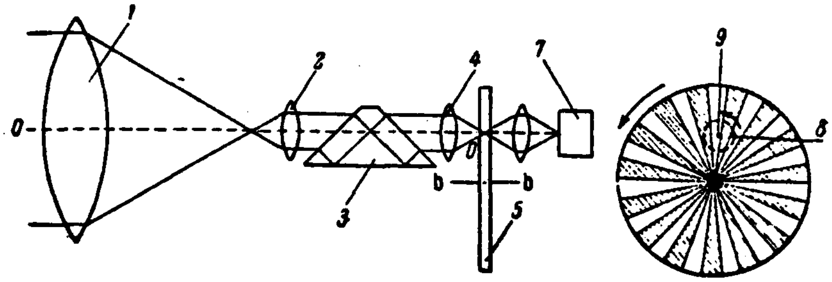

Fig. 41. Follower with rotating Dove prism and rotating modulating disk.

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The schematic diagram of device/equipment is reduced to the following (Fig. 41). objective 1 receives the image of object, and condenser lens 2 guides parallel beam of light to Dove prism 3 rotating around axis O-O. Then lens 4 focuses image on disk 5, which rotates around axis b-b and radiation/emission they enter photocell 7. The rotating Dove prism rotates the passing through it image with the angular velocity, two times of the larger speed of rotation of prism. When

the image of object coincides with the optical axis of system O-O, on disk 5 is obtained point 9. With the divergence of image from axis O-O on the disk appears point 8, which rotates in the circle/circumference with the center at point 9, the direction of rotation to point 8 first coinciding with the direction of rotation of disk 5, then is opposite to it.

Since width of transparent and opaque bands decreases with the displacement to the rotational axis of disk, the larger number of bands will pass per unit time under the image of the object when the latter is located nearer to the rotational axis of disk, than when it is arranged/located on the larger distance. Because of this fundamental frequency (frequency of the rotation of prism) is modulated by supplementary frequency, moreover the phase of modulation is proportional to the angular orientation of object, and the value of modulation is proportional to amount of deflection. Thus, the position of object is determined by the phase shift of the modulated signal and by the value of frequency modulation.

Is developed also the device/equipment, in which for the purpose of obtaining the information about the position of the object of the radiations/emissions, which passed through the rotating Dove prism, are divided with the aid of the mirror prism and are supplied then to two photocells [64]. The schematic diagram of device/equipment is

reduced to the following (Fig. 42). The radiations/emissions of unit are collected by objective 1 and they pass through Dove prism 2, which is rotated by engine 4 (with engine 4 is connected the generator of reference signals 3). Then radiations/emissions fall on dihedral mirror prism 5 and photocells 6 and 7. If the optical axis of system coincides with the direction to the object, then on cathodes of both photocells fall equal and constant luminous fluxes, since the image of object is motionlessly arranged/located on the leading edge of prism. With deviation of the axis of system from the direction to the object the luminescent spot after the Dove prism will describe a circle. In this case on the face of prism 5 and the cathodes of photomultipliers 6, 7 the luminous flux will enter alternately during the half-period in each revolution, i.e., signals from the photomultipliers will be shifted on 180°. For amplifying the error signal is applied push-pull diagram. With this method of tracking the luminous energy is not lost. The direction of disagreement/mismatch is determined by the comparison of the phase of working signal with the phase of reference signal.

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In this case the signal frequency of error is equal to the double frequency of the rotation of the prism of the Doves, since the image passed through it rotates with the angular velocity, two times of the

larger angular rate of rotation of prism itself.

The author together with Ye. P. Chubarov developed several new types of the scanning devices/equipment, which use for the formation of the error signal rotation of image field with the aid of the rotating Dove prism (or the Pechan), and as sensing elements - different types of photoresistors [65].

The schematic diagram of the work of first type scanning device/equipment with the differential photoresistor (for example FS-K7) is given in Fig. 43. For the clarity the radiation source is designed on plane A. Objective 1 of system focuses radiation source to the plane of photoresistor 3 in the form of light spot. Beam of light passes through Dove prism 2 rotating with a constant angular velocity of $\omega/2$. If luminescent spot to value R relative to the axis of optical system, spot by the force of the properties of the rotating prism will be displaced moved on the plane of photoresistor in the circle/circumference of radius r with the angular rate of rotation ω. With R=0 the spot is projected/designed to the center of photoresistor.

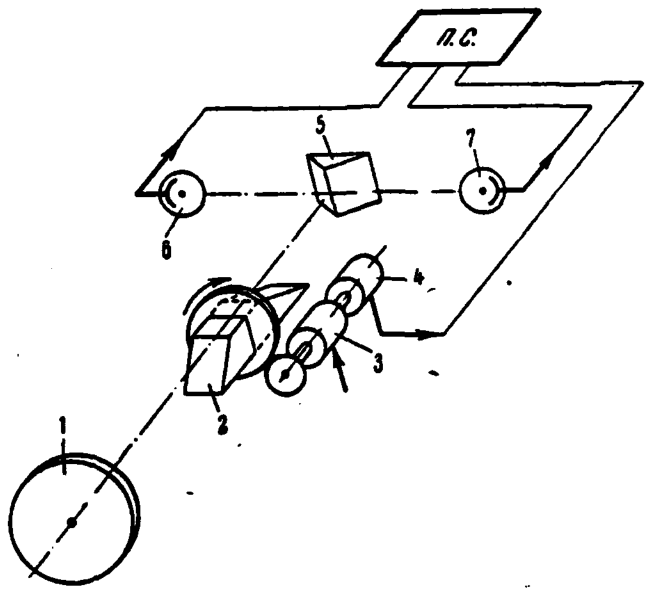

Fig. 42. Servo scanning device/equipment with the rotating Dove prism and two photocells.

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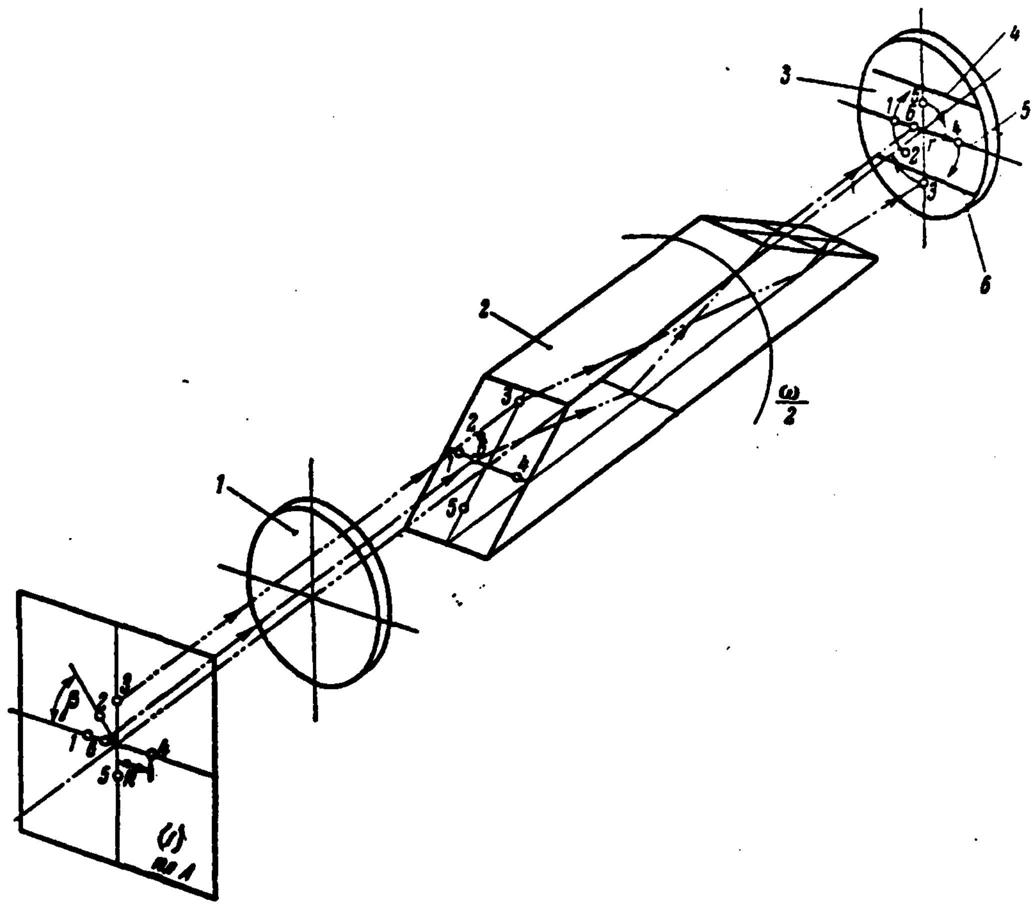

Fig. 43. Schematic diagram of servo scanning devices/equipment with Dove prism and differential photoresistor.

Key: (1). plane A.

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The photosensitive surface of differential photoresistor is divided by parallel electrodes into several parts (in FS-K7a three electrodes, in FS-K7b - five electrodes). Radial deflection terminal is checked in parallel to horizontal plane, and the center of photoresistor is combined with the center of optical system. Upon the entry/incidence of luminescent spot to the photosensitive layer between electrodes 4 and 5 from the photoresistor is removed/taken negative signal, upon the entry/incidence between electrodes 5 and 6 - positive signal.

During the intersection of radial deflection terminal the signal polarity is changed.

Let us assume that the radiation source was displaced to the left (point 1 on plane A). Then in the position of prism indicated in Fig. 43 it will be projected/designed for the radial deflection terminal of photoresistor into point 1. It is analogous point 2, 3, 4, 5 and 6 planes A will be projected/designed into points 2, 3, 4, 5 and 6 planes A will be projected/designed into points 2, 3, 4, 5 and 6 on the plane of photoresistor. If we rotate prism with an angular velocity of $\omega/2$, then luminescent spot will be moved on the photoresistor in the circle/circumference, beginning from point 1, 2,

3, 4, 5 or 6, depending on the direction of the shift of radiation source. In this case the phase of signal U_c, taken from the photoresistor $\Delta\varphi=0-2\pi$, counted off relative to reference signal, will correspond to the direction of the shift of radiation source relative to the optical axis of system (Fig. 44a). Working signal U_c follows with the frequency ω; the reference signal of the same frequency can be formed by one of the known methods. In this device/equipment reference signal is formed/shaped with the aid of the generator whose rotor is given from the engine, which rotates the Dove prism. Voltage frequency, taken from the generator, will be proportional to the angular rate of rotation of prism.

During the shifts of radiation source relative to the optical axis of system, greater than a specific value, this device/equipment puts out the supplementary signal, which corresponds also to the amount of shift; this signal can regulate the speed of bringing by the servomotors of the axis of system to the direction to the radiation source. The formation/education of the signal, which corresponds to the amount of shift, in this case occurs as a result of the output of spot during its motion along the photoresistor for the lateral electrodes (see Fig. 43, point 3). At this time occurs the drop of signal up to zero, and the porosity of the formed impulse/momentum/pulse will be found in the unique dependence on the amount of shift $r\left(r=\frac{h}{\cos\frac{\varphi_c}{2}}\right.$ or

$\varphi_c = 2 \arccos \frac{h}{r}$; $r>h$, where h - distance between the collector strips) (Fig. 44b).

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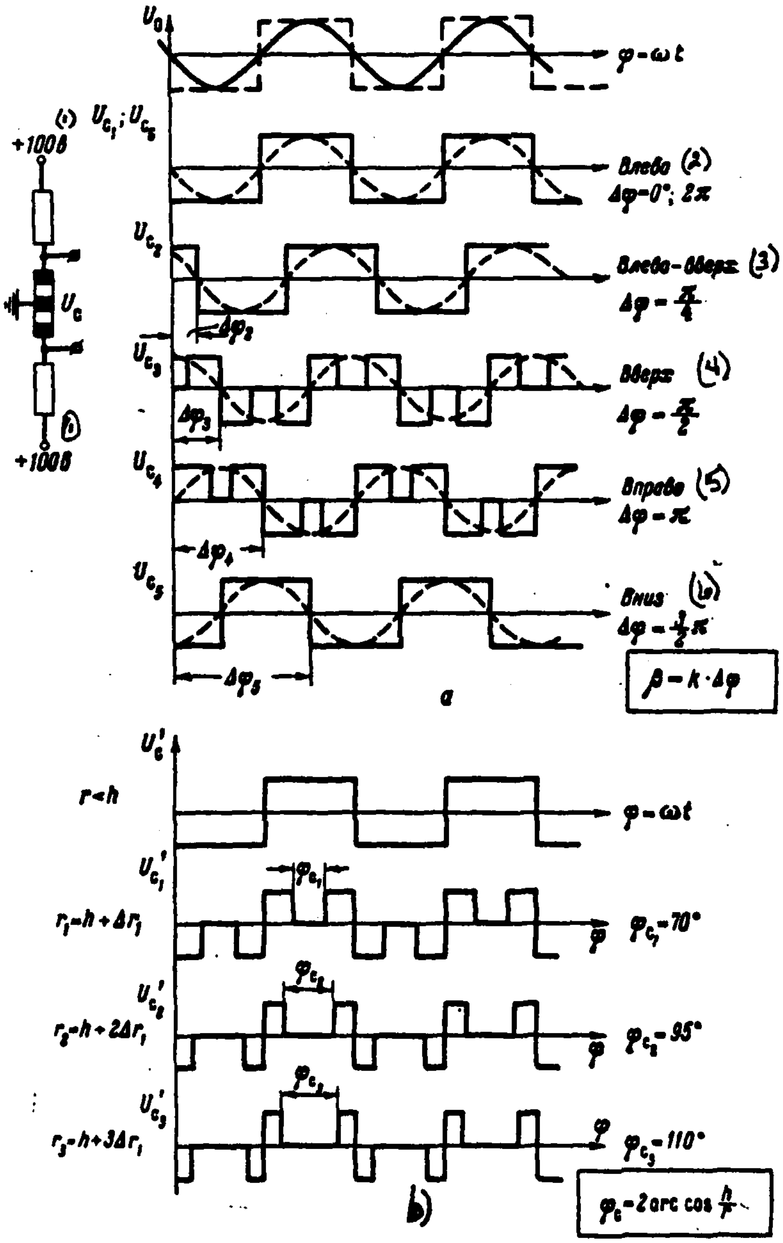

Fig. 44. Change in waveform, obtained on photoresistor of follower during angular (a) and radial (b) shifts of object.

Key: (1). V. (2). To the left. (3). To the left-upward. (4). Upward. (5). To the right. (6). Down.

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In accordance with the operating principle presented it is possible to fulfill the following circuit solutions of delivering the control signals to the servomotors (Fig. 45). The delivery of the signal, proportional to the angle of shift of object β, is realized with the aid of the two-cycle selective amplifier, tuned to a frequency ω, and the phasemeter which enters the reference signal U_0 and intensive and filtered working signal U_c. The use of a selective amplifier makes it possible to raise signal-to-noise ratio. The sensitivity of diagram is raised as a result of the bipolarity of working signal; in this case the losses of luminous energy does not occur.

The diagram of the creation of signal, proportional to the value of deflection of object (with r>h), consists of push-pull amplifier, meter of porosity and resolver, which linearizes dependence of R on $\varphi_0/2$. The meter of porosity fills holes with the impulses/momenta/pulses of the stabilized frequency and determines a

number of filling impulses/momenta/pulses.

The second type of servo scanning device/equipment [65] developed in IAT utilizes as sensing element a photoresistor with the photosensitive strip. The operating principle of device/equipment is represented on Fig. 46. In this case the position of photosensitive strip is checked so that it by one end/lead would concern the optical axis of system. During the rotation of the Dove prism the luminescent spot, focused to the plane of photoresistor with objective 1, will intersect photosensitive strip, putting out pulse signal.

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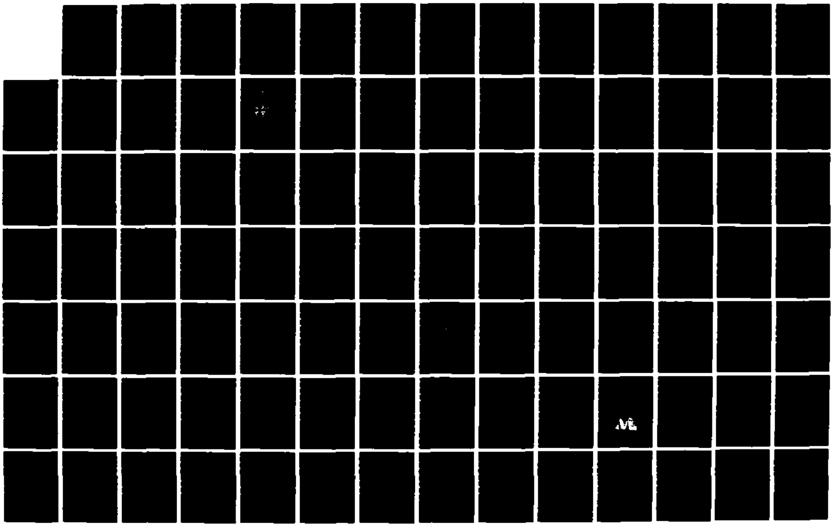

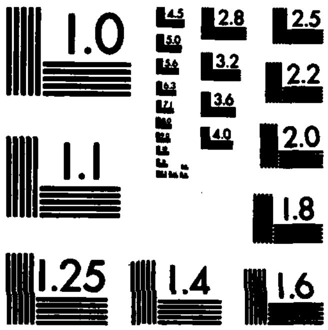

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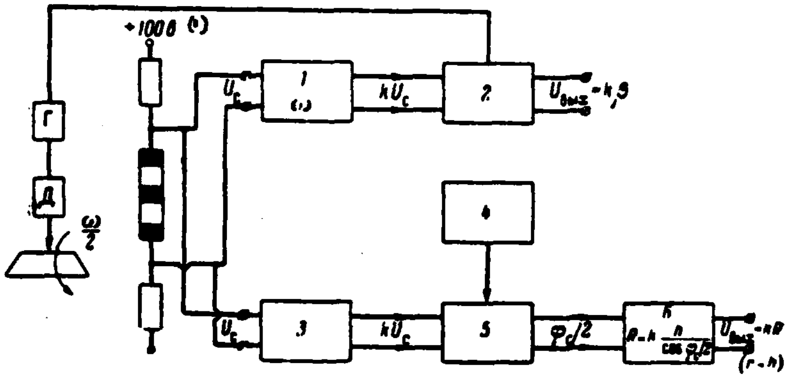

Fig. 45. The block diagram of follower with the Dove prism and the differential photoresistor: 1 - two-cycle selective amplifier; 2 - phasemeter; 3 - push-pull amplifier; 4 - generator of the filling impulses/momenta/pulses; 5 - meter of porosity; 6 - resolver.

Key: (1). V.

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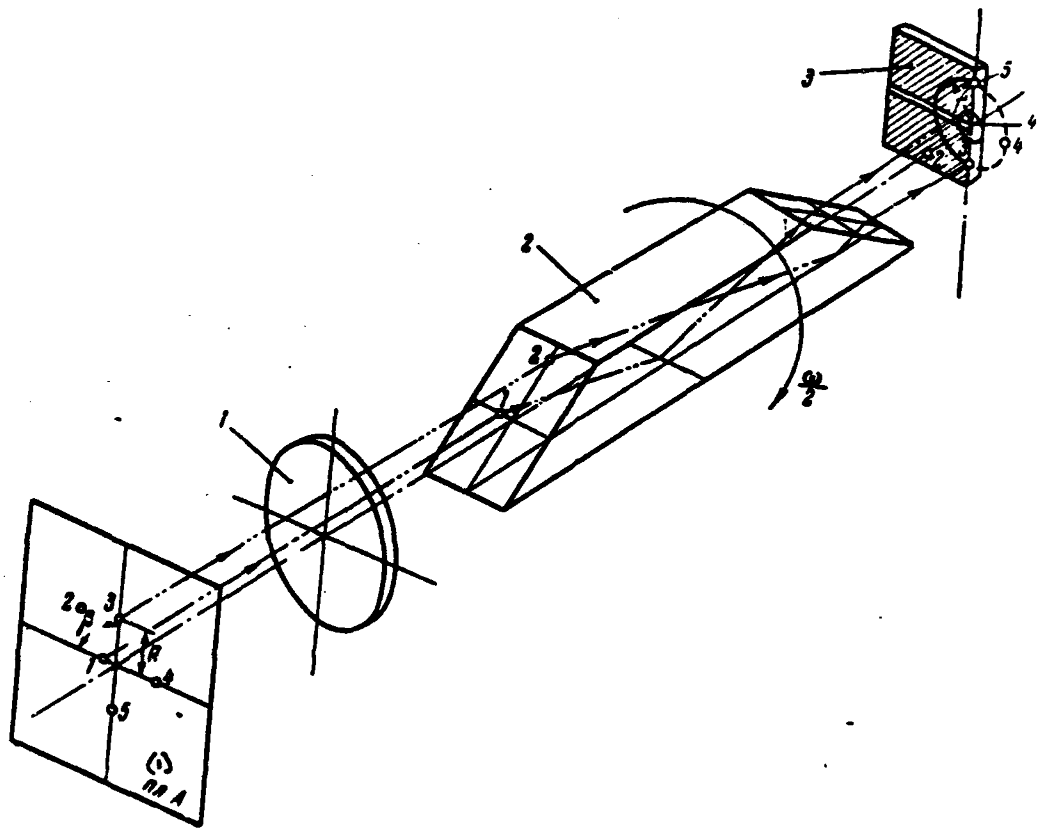

Fig. 46. Schematic diagram of follower with Dove prism and band sensing element: 1 - objective; 2 - Dove prism; 3 - photoresistor; 4 - photosensitive strip.

Key: (1). Plane A.

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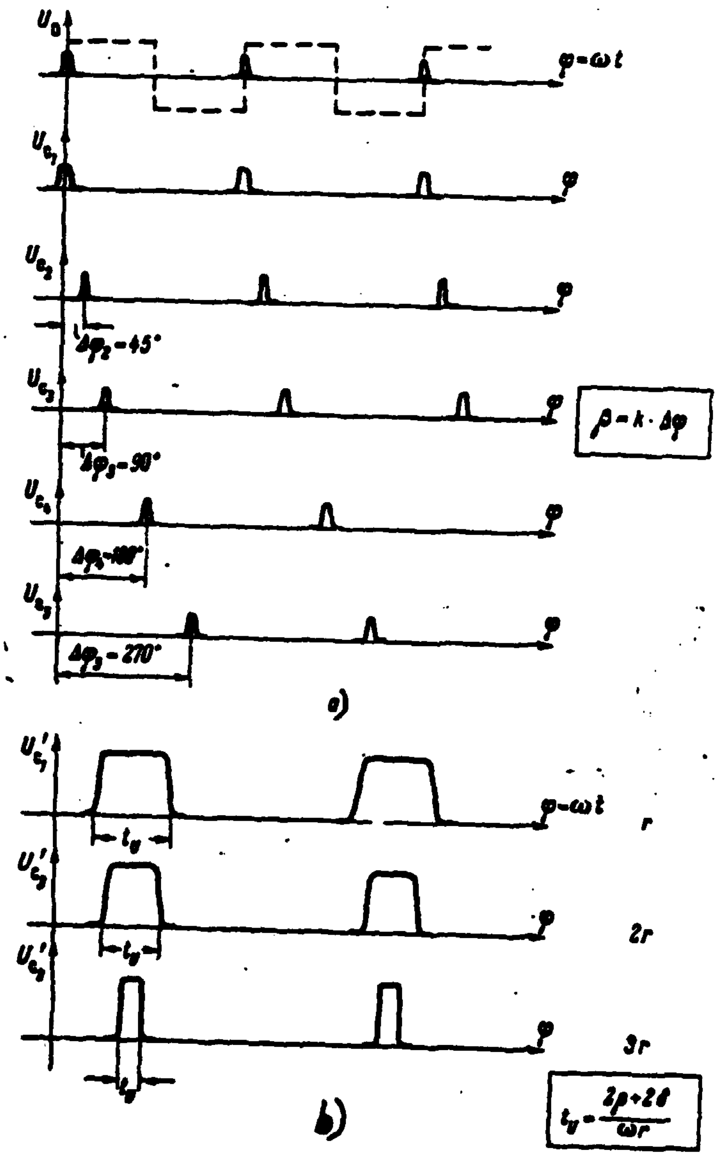

Fig. 47. Change in waveform of photoelectric follower during angular (a) and radial (b) shifts of object.

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Time delay between the reference pulses and the workers, as in the preceding/previous device/equipment, it will correspond to the direction of the shift (to value of angle β) of radiation source relative to the axis of system (Fig. 47). If shift is equal to zero, then from the photoresistor will be removed/taken steady signal.

With the unchanging value of the diameter of luminescent spot it is possible to determine the amount of shift, measuring the latitude of impulse/momentum/pulse (or the ratio of its duration to the period). The latitude of impulse/momentum/pulse (Fig. 47b) will be connected with a radius with inversely proportional dependence which is examined below.

The block diagram of the described device/equipment is represented in Fig. 48. The impulses/momenta/pulses entering from the photoresistor are amplified and are supplied on the input of the measuring unit of the pulse duration and then on the input of resolver, which puts out the signal, proportional to the amount of shift. Simultaneously signal from the photoresistor is supplied also to the input of the channel of the determination of the direction of shift. In the latter is conducted the filling with the stabilized impulses/momenta/pulses of time interval between the reference pulse

and the worker. Then a quantity of filling impulses/momenta/pulses is computed. The obtained signals enter the servomotors of follower.

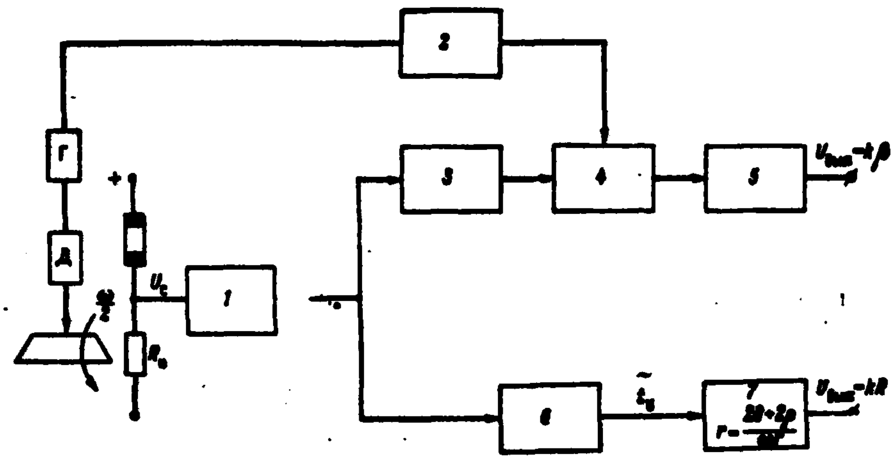

Fig. 48. The block diagram of follower with the rotating Dove prism and the banded photoresistor: 1 - amplifier; 2 - shaper of reference pulses; 3 - shaper of operating pulses; 4 - generator of the filling impulses/momenta/pulses; 5 - pulse counter; 6 - meter of the pulse duration; 7 - resolver.

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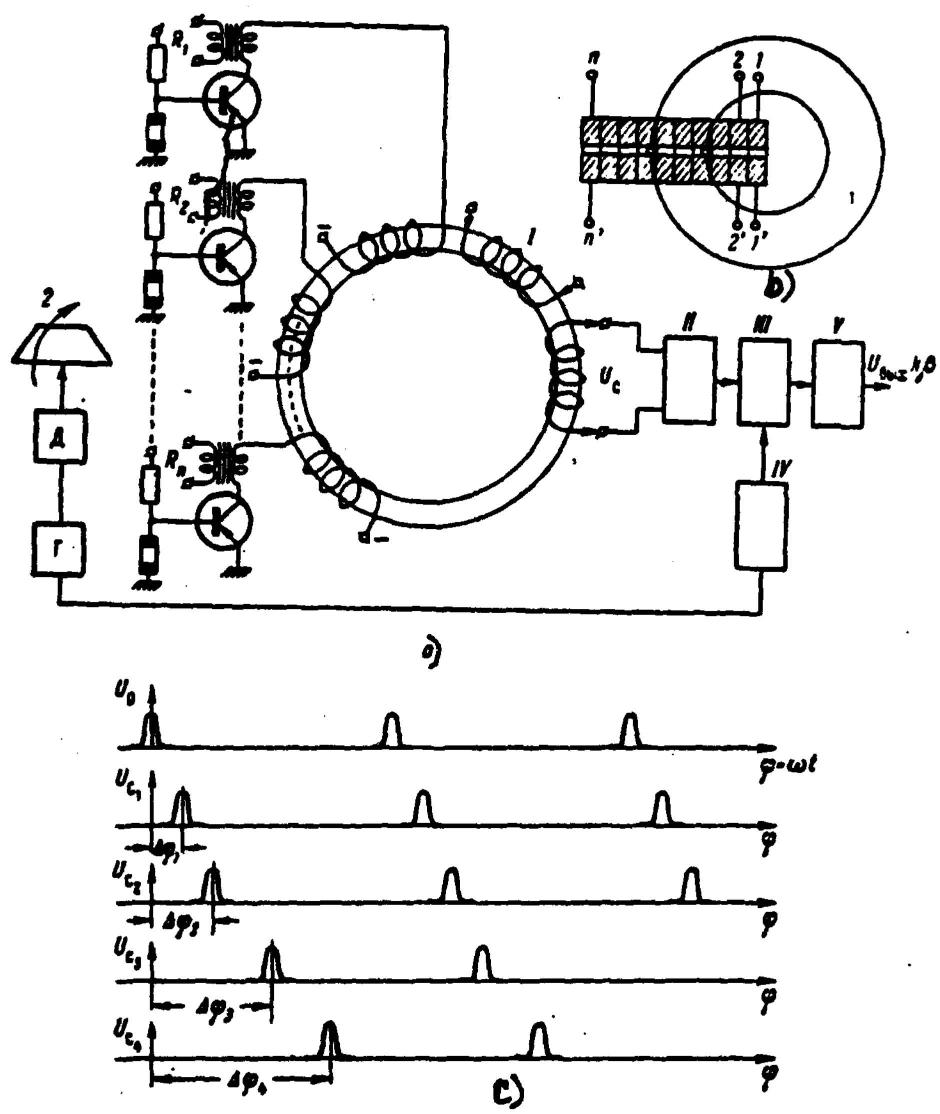

Fig. 40. The block diagram of follower with the Dove prism and the photosensitive strip, assembled from the elementary photoresistors (a), the execution of photosensitive strip (b), the form of the

electrical signals, obtained from the device/equipment (c): I - winding of clock impulses/momenta/pulses; II - amplifier and the shaper of operating pulses; III - generator of the filling impulses/momenta/pulses; IV - shaper of reference pulses; V - pulse counter.

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In this device/equipment instead of the photoresistor with the photosensitive strip can be used the photomultipliers whose photoelectric cathodes are closed with screen with the slot, or photodiodes and the phototriodes of the corresponding construction/design. It is necessary to note that to the accuracy of this device/equipment can affect the pulse interferences (stably repeating).

In the third type of the scanning device/equipment, developed in IAT, is utilized the analogous principle of the delivery of the signal, proportional to the direction of shift. However, for the fixation of the amount of shift photosensitive strip is comprised from the specific number of small photoresistors of the type FS-K5 with the value of photosensitive layer in 0.5x0.5 mm^2 (Fig. 49b).

Luminescent spot will intersect one or the other photoresistor

on which will appear the signal, which is determining the amount of shift.

Electrical circuit (Fig. 49a) consists of n preamplifiers and "OR" gate, at output of which will appear impulse/momentum/pulse U_c, if luminescent spot crosses any of the photoresistors. For this to the ferrite ring is coiled n of the identical windings, connected in the circuit of preamplifiers. Clock impulses/momenta/pulses transfer/translate diagram into the initial position after the arrival of next operating pulse. Signal from the "OR" gate ($\dot{U}_c$) enters the channel of the measurement of the direction of shift, which is conducted in the value of the shift of operating pulse relative to supporting/reference. In the circuit of preamplifiers are connected also the windings, which fix the passage of spot on this photoresistor, which corresponds to the specific amount of the shift of object relative to the optical axis of system.

The diagram examined is also subjected to the effect of interferences and noises; however, in view of its integrating properties the accuracy of its work is sufficiently high.

Work [66] gives basic calculated dependences for devices/equipment examined above. Let us lead them into a somewhat abbreviated/reduced form. We will consider that the luminescent spot,

focused to the plane of photoresistor, has the not changing in the process of observation size/dimension 2ρ (diameter with the circular spot or side of square with the square spot). The width of radial deflection terminal let us designate 2δ, the width of the photosensitive strip d, distance from the radial deflection terminal to lateral h. The distribution of the luminous flux according to the spot we will consider uniform.

The value of the photo current of photoresistor I_Φ will be determined by the value of the luminous flux Φ and by the value of the applied to it stress/voltage U:

$$I_\Phi = k_0 U \Phi,$$

where k_0 - specific sensitivity of photoresistor, μA/lm·V.

In turn, $\Phi = ES \cdot 10^{-4}$, where S - area of the illuminated section of photoresistor (cm^2), and E - illumination of this section (lux).

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We accept constants the stress/voltage, applied to the photoresistor, and the illumination, created by luminescent spot. Thus, we obtain:

$$I_\Phi = k \cdot 10^{-4} ES = KS,$$

where $K = k_0 U \cdot 10^{-4} E$, i.e. the law of a change in the photo current, or the signal, taken from the photoresistor, is analogous to the law of

a change in the area of the illuminated photosensitive section.

In the first type of the scanning device/equipment (see Fig. 43) value S will change during the intersection with the luminescent spot of electrodes. During the intersection of radial deflection terminal will be observed the picture, represented in Fig. 50, I. In work [66] are derived some laws for the luminescent spot of square form, in this case are accepted the following designations: φ - current position angle of the center of spot ($\varphi=\omega t$), counted off from the horizontal level; f - height/altitude of the spot above the horizontal axis which is combined with the average of the lines of radial deflection terminal; Δ - value of the height/altitude of the element/cell of spot, which is located out of the electrode. With $\rho<\delta$ we have: $\Delta+\delta=f+\rho$; $\Delta=f+\rho-\delta$; $f=r \sin\varphi$. As a result of $S=2\rho\Delta=2\rho(\rho-\delta+r \sin\varphi)$ and $I_\Phi = K2\rho(r\sin\varphi - \delta + \rho)$.

With $\rho>\delta$ (Fig. 50, I, b; 50, II, d) the differential signal, taken from both halves of photoresistor, can be expressed as follows:

$$I_{\Phi} = I_{\Phi_1} - I_{\Phi_2} = K(S_1 - S_2),$$

where S_1, S_2 - areas of the illuminated surface of the photosensitive layer of the upper and lower parts of the photoresistor.

Diagram will be insensitive with $r \leqslant \delta - \rho$, i.e., with $\delta > \rho$, in this case $\Delta_1 + \delta = f + \rho$, $\Delta_2 = \rho - \delta - f$, and respectively $S_1 = 2\rho(\rho - \delta + r \sin\varphi)$ and $S_2 = 2\rho(\rho - \delta - r \sin\varphi)$.

Thus, for first type examined devices/equipment it is possible to recommend relationships/ratios $\delta \to 0$, $\rho \to \min$, $\delta \leqslant \rho$.

We investigate dependence $I_{\Phi} = f(\rho, \delta, r)$ and $I_{\Phi} = f(\varphi)$. We note that $0 \leqslant \Delta \leqslant 2\rho$ and $0 \leqslant S \leqslant 4\rho^2$. Then:

1) with $S=0$, $\rho - \delta + r \sin\varphi_0 = 0$, where φ_0 - maximum value of the angle, at which there is no signal from the photoresistor (dead zone):

$$\sin\varphi_0 = \frac{\delta - \rho}{r}.$$

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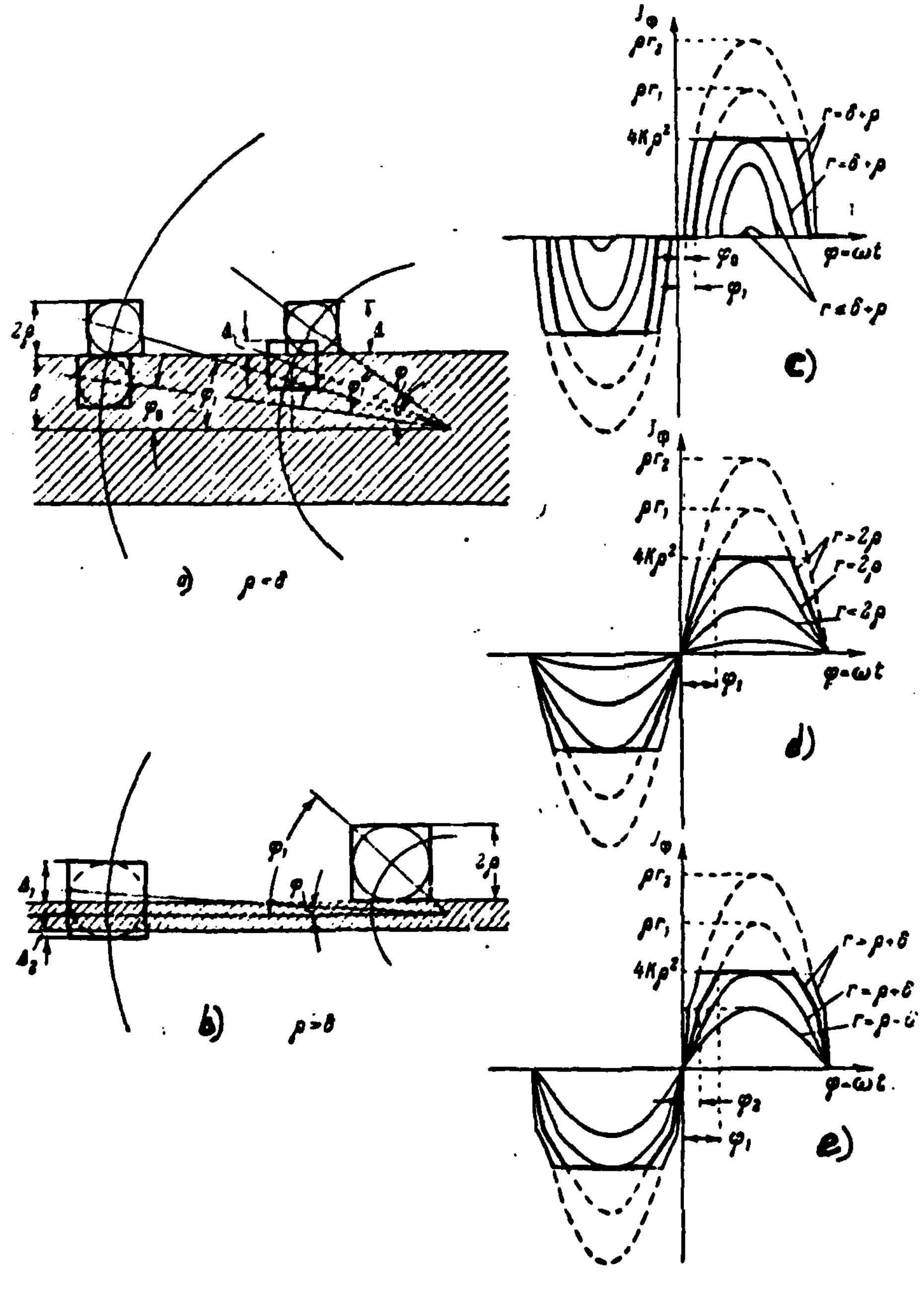

Fig. 50. I - relationship/ratio of image sizes of object and central

contact strip of differential photoresistor for case when image size of object is less (a) and is more (b) width of collector strip. II - signal aspect, obtained from the follower in the case when $\rho<\delta$ (c), $\rho>\delta$ (d), $\rho>\delta$ (e).

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This formula is valid for the square and circular spots;

2) with $S=4\rho^2$, $2\rho^2-2\rho\delta+2\rho r\sin\varphi_1=4\rho^2$ or $r\sin\varphi_1-\delta-\rho=0$, where φ_1 - value of the angle, which corresponds to the end/lead of the build-up of signal (value of pulse edge). As a result

$$\sin\varphi_1=\frac{\delta+\rho}{r}.$$

This formula is also valid also for the circular spot.

With $\rho>\delta$ $\varphi_0=0$, $\Delta_2=\rho-\delta-r\sin\varphi>0$, $\sin\varphi_2=\frac{\rho-\delta}{r}$,

where φ_2 - value of the angle at which the luminescent spot ceases to illuminate lower half of photoresistor. At this time

$$I_\Phi=K2\rho\left(\rho-\delta+r\frac{\rho-\delta}{r}\right)=K4\rho(\rho-\delta).$$

With $\varphi<\varphi_2$

$$I_\Phi=K(S_1-S_2)=K4\varrho r\sin\varphi;$$

with $\varphi_2<\varphi<\varphi_1$

$$I_\Phi=KS_1=K2\varrho(\varrho-\delta+r\sin\varphi);$$

with $\varphi > \varphi_1$

$$I = K2\rho\left(\rho - \delta + 2\frac{\rho + \delta}{r}\right) = K4\rho^2.$$

Generalizing the given formulas, it is possible to give the following general/common/total expression for the dependence of the photo current of the differential photoresistor (this illustration of dependence see in Fig. 50):

with $\rho < \delta$

$$I_\Phi = \begin{cases} 0 & 0 \leqslant \varphi \leqslant \varphi_0 \quad \sin\varphi_0 = \dfrac{\delta - \rho}{r} \\ K2\rho(r\sin\varphi - \delta + \rho) & \varphi_0 < \varphi \leqslant \varphi_1 \\ K4\rho^2 & \varphi_1 < \varphi \leqslant \dfrac{\pi}{2} \quad \sin\varphi_1 = \dfrac{\delta + \rho}{r} \end{cases}$$

(see Fig. 50, I, a; Fig. 50, II, c);

with $\rho = \delta$ $$I_\Phi = \begin{cases} K2\rho r\sin\varphi & 0 \leqslant \varphi \leqslant \varphi_1 \quad \sin\varphi_1 = \dfrac{\delta + \rho}{r} \\ K4\rho^2 & \varphi_1 < \varphi \leqslant \dfrac{\pi}{2} \end{cases}$$

(cm Fig. 50, II, d);

with $\rho > \delta$

$$I_\Phi = \begin{cases} K4\rho r\sin\varphi & 0 \leqslant \varphi \leqslant \varphi_2 \\ K2\rho(r\sin\varphi + \rho - \delta) & \varphi_2 < \varphi \leqslant \varphi_1 \quad \sin\varphi_2 = \dfrac{\rho - \delta}{r} \\ K4\rho^2 & \varphi_1 < \varphi \leqslant \dfrac{\pi}{2} \quad \sin\varphi_1 = \dfrac{\rho + \delta}{r} \end{cases}$$

(see Fig. 50, I, b; Fig. 50, II, d).

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The author together with Ye. P. Chubarov developed experimental laboratory model of scanning devices/equipment with the Dove prism and the differential photoresistor of the type FS-K7a (Fig. 51). The rotation of prism is realized from the synchronous motor of the type SD-60 with the aid of the gear drive. In this case can be created three speeds of rotation of prism - 20, 200 and 2000 r/min. Engine and generator of reference signals are installed on one plate/slab. The rotation of draw tube with the prism occurs in two bearings. In the forward section of the housing is arranged/located the objective. The housing of the drive of prism is established/installed on the plate/slab on which is also installed the photoresistor. For the light protection of the scanning device/equipment is provided special bellows. Tests of the scanning device/equipment yielded positive results.

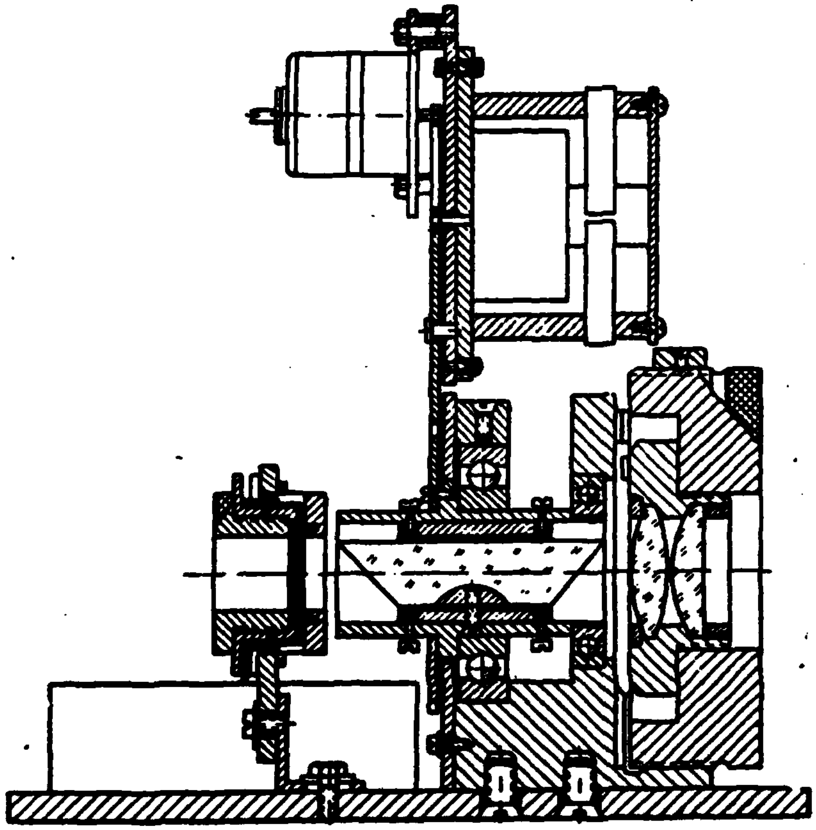

Fig. 51. follower with the rotating Dove prism and the differential photoresistor.

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In conclusion it is necessary to note that the improvement of technology of the production of the electrodes of differential photoresistors (for the purpose of the decrease of their width to 0.1-0.01 mm) considerably decreases the dead zone and will increase

the accuracy of first type developed device/equipment. With sensitization of photoresistors and decrease of the width of electrodes and photo-strip will appear the possibility of tracking with the high accuracy the radiation sources of a small power and value. Weight and overall sizes of devices/equipment can be reduced by using it for rotating the prism of special engines with the complete rotor and applying the more qualitative small optic/optics.

The devices/equipment examined possess the series/row of the positive qualities, from which basic are the absence in the diagram of high voltages, a small cost/value of elements/cells, the insignificant effect of temperature and the absence of the dependence of readings/indications on value and frequency of the feeding stress/voltage.

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Section IV.

Elements of the scanning systems in which scanning~~/sweep~~ of image is realized by the mechanical displacements of scanning beam.

In the systems of this class to focuser and to sensing element those scanning movements are given by means of special mechanisms. In comparison with the photoelectric ones and the the optical-mechanical these systems possess comparatively low dynamic properties, but their advantage is simplicity of electrical and optical diagrams.

Such systems can be made in the form of the scanning platforms, powered with the aid of one or several electric motors and special three-dimensional-mechanical converters. On this scanning platform can be placed sensing element of any operating principle. In particular, on this scanning platform can be established/installed pyrometers of any type (radiation, brightness or color), which can monitor the state of temperature field.

Some operating principles, placed as the basis of the scanning systems of this type, are to a sufficient degree general/common/total with the optical-mechanical mirror scanning devices/equipment, examined in section II. However, they have a series/row of essential differences from the optical-mechanical devices/equipment. In particular, in the devices/equipment with the scanning platforms of the masses, which accomplish three-dimensional/space displacements, they have the significant magnitude. Therefore during the construction of such devices/equipment it is necessary to fulfill the calculation of the elements/cells of actuators taking into account inertia loads, and to also determine the dynamic balance of the mechanisms. By this is explained the isolation/liberation of the given scanning systems into the separate section of a book.

The creation of mechanisms for the scanning platforms is possible on two in principle different paths.

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In the first case of the displacement of the scanning platform they reproduce in the miniature the trajectory of scanning beam on the controllable/controlled/inspected field. If in this case are realized

rotations and inclinations/slopes of platform, then they are intended only for the increased reproduction of trajectory of scanning in the controllable/controlled/inspected field. The central point of this platform describes the trajectory of scanning.

In those scanning devices/equipment, that act according to the second principle, the platform does not complete the linear displacements (its central point is motionless or is moved in the very small limits). In this case the trajectory of scanning is reproduced via the corresponding inclinations/slopes of the scanning platforms relative to the axis system.

Below are examined mechanisms of both groups of the scanning devices/equipment.

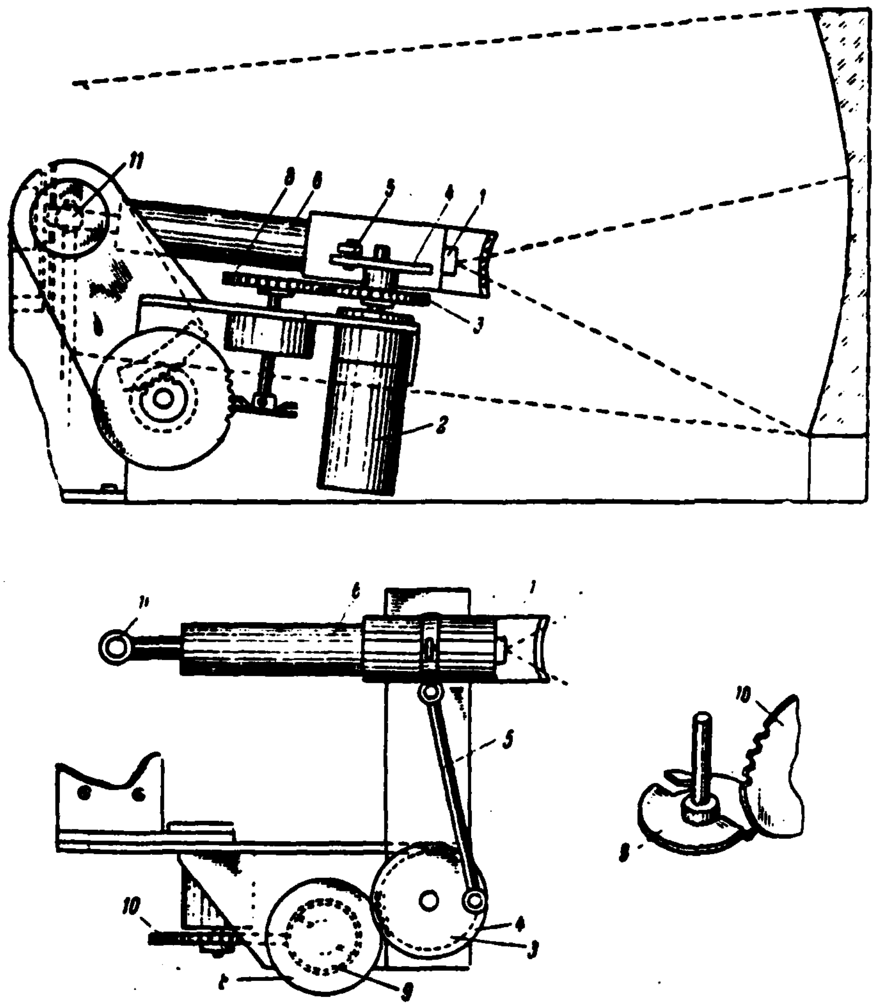

Fig. 52. Mechanical scanning device/equipment by movement of sensing element in the sphere.

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Chapter 11.

Mechanisms, which realize displacement of scanning beam over the line-by-line trajectory.

In the mechanisms of this type the trajectory of scanning, as a rule, is formed/shaped by the adding of two oscillatory motions. In this case are applied in the different combinations different types of the converters of rotary motion into the reciprocating (oscillatory) motion.

Let us begin the examination of the scanning devices/equipment of this class from the device/equipment, represented in Fig. 52. Scanning is realized by mechanical displacement of detector 1 in two mutually perpendicular directions [67]. Horizontal sweep is conducted with the aid of engine 2 and crank mechanism 3, 4 whose thrust/rod of 5 is hinged connected with the housing of 6 detectors 1. During its motion the detector with the aid of the spring is forced against fee/pay/board 1. Vertical sweep is accomplished with the aid of pinion drive 3, 8, cam device/equipment 9 and gear 10. Transmission is calculated in such a way that for those two scanning motions in

the horizontal direction gear 10 is moved to two teeth. Horizontal and bouncing is produced relative to spherical bearing 11, which is located in the center of curvature of spherical mirror.

Scanning field on the the line-by-line trajectories can be made also with the aid of the three-dimensional/space mechanism, which has two separate drives [68]. This device/equipment is represented in Fig. 53.

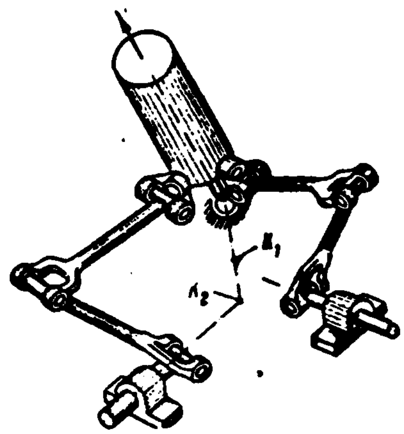

Fig. 53. A search-servo scanning device/equipment with the preset laws of the motion of driving/homing axes.

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It is fulfillied in the form of the doubled multilink mechanisms each of which consists of the leading component/link and three-link articulated link chain with the parallel fulcrums and driven/known component/link with the ball joint, not lying in the plane, passing through the axes of the leading components/links.

Guide mechanism depending on stated problem is fulfilled with one or two guides. In that and in other case each guide is the multilink mechanism, which encompasses three-link mechanism with parallel axes, articulated link chain which from one side is articulated with the leading component/link, and with another - with

consent, equipped with the ball joint. For guaranteeing the continuous focusing/induction of the driven/known component/link guide mechanisms can be made in the form of the dual multilink mechanisms with one pole or multilinkage with the diverse poles K_1 and K_2.

Let us examine the scanning device/equipment in which for the realization of line-by-line scanning/sweep is used spherical mechanism (Fig. 54). The mechanism of line scanning is a three-dimensional-mechanical converter of rotating motion into the oscillatory, by basic node/unit of which is crankshaft 1 with inclined neck 2. In this mechanism as the guide, which creates the flat/plane oscillatory motions of yoke/arm 3, used is a bracket with the flat/plane slot/groove, on which is moved the cylindrical pin of yoke/arm. Frame scan is realized by displacement of bearing slot/groove 4 in the direction, perpendicular to the plane of vibration of yoke/arm 3. This is fulfilled with the aid of cam gear 5.

Kinematics and dynamics of this three-dimensional/space mechanism are examined on page 112. Its positive quality is simplicity of construction/design in comparison with the devices/equipment with cardan mounting of the draw tube of the photoelectric device/equipment, powered with the aid of supply.

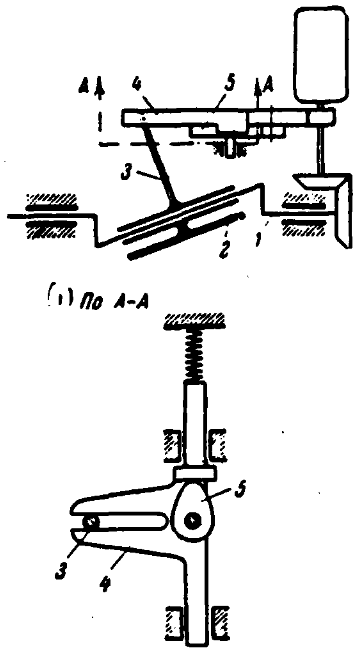

Fig. 54. The search mechanical scanning device/equipment in which is used three-dimensional-spherical actuator of platform.

Key: (1). On A-A.

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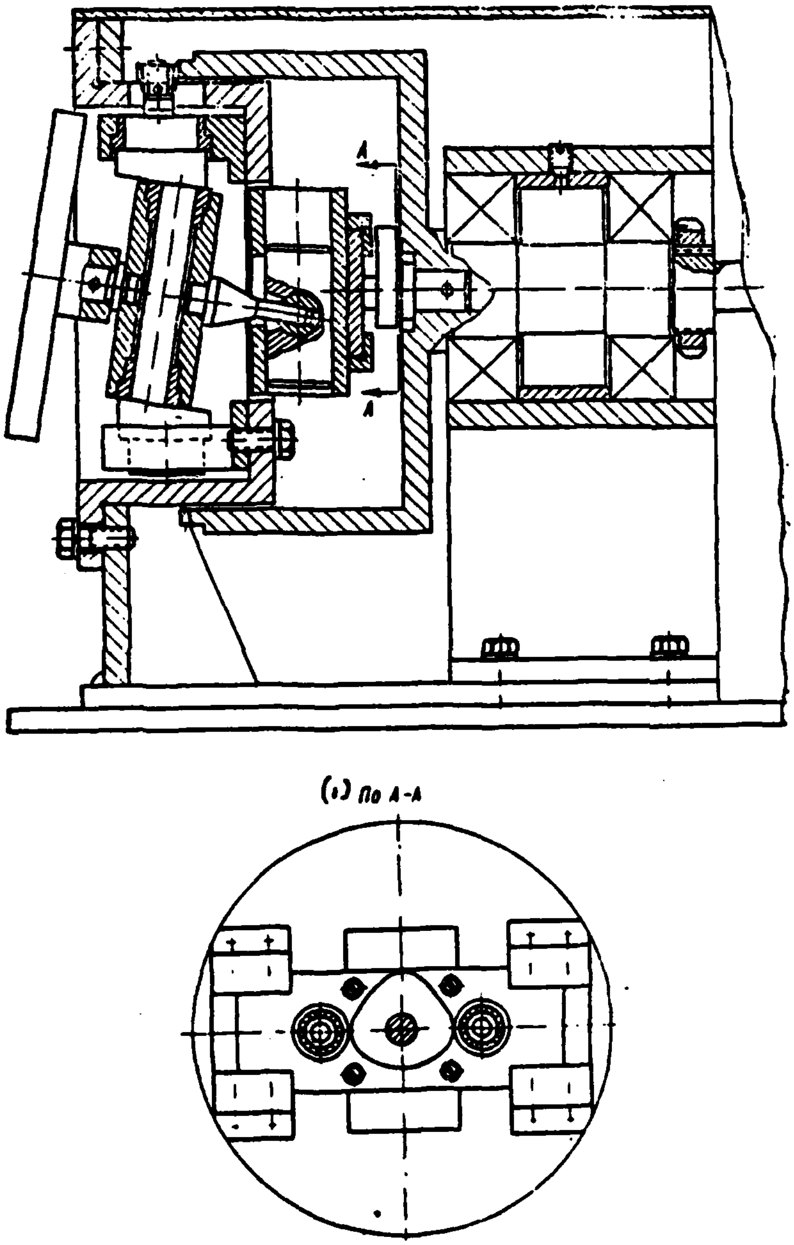

Fig. 55. Scanning device/equipment with line-by-line trajectory of scanning.

Key: (1). On A-A.

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On the basis of operating principle examined above in the institute of automation and telemechanics the author with the group of colleagues [1] developed the scanning device/equipment, represented in Fig. 55.

FOOTNOTE [1]. In the development took part I. K. Mel'nichenko, O. I. Karyagin, V. A. Abrikosov. ENDFOOTNOTE.

In it, as in preceding/previous, is used the spherical mechanism of the swaying yoke/arm; however, its drive is made otherwise. In this case the axis of drive motor is arranged/located on the optical axis of device/equipment. For the creation of the plane oscillation of yoke/arm is used the piston mechanism which is joined with those swaying by yoke/arm with the aid of the telescopic joint. This piston is moved in the supporting cylinder. For compiling of the line-by-line trajectory of scanning the axis of supporting cylinder with the aid of the cam mechanism is moved in the vertical plane.

In this device/equipment the signals of scanning/sweep of electron beam in the block/module/unit of reconstruction of image are formed/shaped into four special sensors, mounted on the electromechanical scanning device/equipment. With the aid of these signals in the reproducing block/module/unit are realized the motions of electron beam, synchronous with the motions of scanning beam in the analyzing block/module/unit.

This device/equipment has the following characteristics: is produced scanning along the line-by-line trajectory, which has 20 rows; the period of scanning is 80 s. It can be used for monitoring of temperature fields, in this case on the *scanning* platform can be established/installed the sighting cap/knob of any optical pyrometer or another device/equipment.

Chapter 12.

Planetary and three-dimensional~~/space~~ mechanisms, which realize displacement of scanning beam over the rotational-rotational trajectory.

In the scanning mechanisms of this group the trajectory of scanning is formed/shaped by adding two rotary motion. Because of this the device/equipment of this group, as a rule, have simpler diagrams than actuators examined higher of the scanning platforms, the realizing line-by-line trajectories of scanning.

In the majority of the mechanisms in question, which accomplish scanning as on the rotational-rotational, so also on the vibrational-rotational to trajectories, the scanning platforms complete rotating motion. Therefore the electrical elements/cells established/installed on them during the scanning also complete rotary motion.

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The consequence of this is the need for use/application in such devices/equipment of the sliding slip rings. However, some scanning

systems in question can be made in the form of versions with the nonrotating platforms. In the majority of the cases in such devices/equipment the draw tube with the objective and by sensing element is established/installed on the nonrotating scanning platform, arranged/located on the gimbal suspension. In this case on the scanning mechanism is placed the guide cylindrical pin which is connected with the scanning draw tube with the aid of universal joint with the telescopic articulation (in this case rotary motion are not transmitted to the scanning draw tube, since occurs the rotation of guide pin in the telescopic articulation of universal joint).

In view of the fact that this attachment can be established/installed to the identical degree in all mechanisms considered/examined below of the scanning platforms, it, as a rule, is not examined.

Some mechanisms of the scanning platforms as a result of the specific character of diagram it is possible to fulfill in two versions - with the rotating and nonrotating platform. Here, the mechanism with the nonrotating is fulfilled not with the aid of the examined above standard attachment, established/installed in the gimbal suspension, but by the inclusion into the structure of the mechanism of the supplementary component/link which makes it possible to exclude the rotary motion of the scanning platform. Several scanning mechanisms of such type

are examined below. Their device/equipment is simpler than in the analogous scanning mechanisms with the supplementary attachment, which has gimbal suspension.

In the dependence of the type of the photoelectric device/equipment, adjusted on the scanning platform (its complexity, the ability normally to work during the rotation around the optical axis of a quantity of required electrical introductions/inputs, etc.), most rational can prove to be either the use of the scanning mechanisms, which accomplish together with the scanning motion also the rotary motion of platform, or - the scanning mechanisms, in which the rotary motion of platform is absent. As a rule, first type of mechanisms (with the rotating platform) are simpler than second type mechanisms. But in this case appears the series/row of the supplementary noted above difficulties among which especially should be noted the difficulties with feed through to the elements/cells of device/equipment, established/installed on the rotating platform, and also with the conclusion/output of the obtained signal.

The type of the scanning mechanism (with the rotating or nonrotating platform) necessary to select, proceeding from what type of the scanning platform in the sum with the established/installed on it optico-electrical elements/cells will prove to be more simply.

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The fact is that the introduction of the device/equipment, which stops the rotation of platform, as a rule, leads to certain complication of the scanning mechanism. Therefore, if the elements/cells adjustable on the scanning platform allow/assume the presence of rotary motion and have comparatively small quantity of conclusions/outputs, then to more rationally utilize the scanning mechanism with the rotating platform. Otherwise it is necessary to utilize the scanning system with supplementary mechanism, which eliminates the rotation of the scanning platform.

As an example of actuators of the scanning platforms of first type there can be examined are the following devices/equipment.

For scanning of field along the socket rotary-rotary trajectory (see Fig. 1) it is possible to utilize the three-dimensional/space mechanism, represented in Fig. 56. In this device/equipment sensing element ChE is established/installed on guide 5 which is rotated of gear 4, rolled on motionless gear 3 (during the rotation of gear 2 from engine 1). In this case gear 4 completes differential motion, and sensing element realizes simultaneously rotation around the axes O_1-O_1 and O_2-O_2. The supply of sensing element and the removal/output of signal in this device/equipment are conducted by slip rings [69].

Let us examine the device/equipment of actuator of scanning platform [69], represented in Fig. 57a. In this mechanism during the rotation of housing 5 from electric motor 6 crankshaft 1, which has inclined neck 2, rotates by gear 3, rolled on motionless gear 4. During the rotation of shaft 1 stock/rod 7, fastened/strengthened to bushing 8, completes three-dimensional/space displacements, moreover its axis moves over the cone. This occurs as a result of the fact that stock/rod 7 is held from the displacement with the aid of turned stock/rod 11 with eccentrically fastened/strengthened to it cylindrical finger/pin 10. The latter is supported in the articulation with the circular (toroidal) annular groove of stock/rod 7 with the aid of figure part 9. The sizes/dimensions of parts 7, 9, 10, 11 are designed in such a way that the axis of stock/rod 7 during the rotation of shaft 1 evenly would be moved over the conical surface. In this case stock/rod 11 rotates in the cylindrical opening/aperture of housing.

Let us determine, what type of trajectory will describe the scanning platform with actuator of such type.

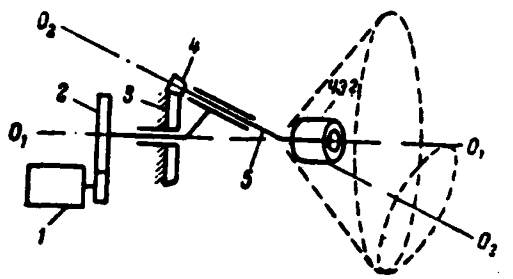

Fig. 56. Scanning device/equipment with planetary train, which realizes a rotary-rotary trajectory.

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If we do not consider the rotary motion of housing 5 and to consider that shaft 1 is rotated from the supplementary engine, then in this case scanning platform 12, connected with parts 7 and 8, will describe symmetrical spherical motion. Consequently, the trajectory of the scanning spot of this device/equipment will represent circle/circumference with the center, which lies on the axis of the symmetry of device/equipment. For the realization with the aid of the mechanism of the rotational-rotational trajectory of scanning examined with the relationship/ratio of the parameters 2r=R (see Fig. 1) it is necessary that the mechanism would have such parameters, in which in one of the end positions of the crank shaft the plane of scanning platform was perpendicular to the rotational axis of housing. This can be performed by the installation of the crank shaft

at the specific angle to the rotational axis of housing (Fig. 57b). In this case the spherical displacements of scanning platform being composed with the rotary motion of the housing of mechanism, will realize a rotational-rotational trajectory of scanning (with 2r=R).

In view of the fact that in the mechanism of this type during the rotation of crankshaft, beginning from any end position, the holding stock/rod can start up in any direction, it is necessary with the aid of the special drive to impart to it forced rotation of determinate direction. The device/equipment of this drive is represented in Fig. 57b. The rotation of stock/rod is created by rolling the gear established/installed on it on the motionless gear. In this case the number of revolutions of stock/rod must be equal to the number of revolutions of crankshaft.

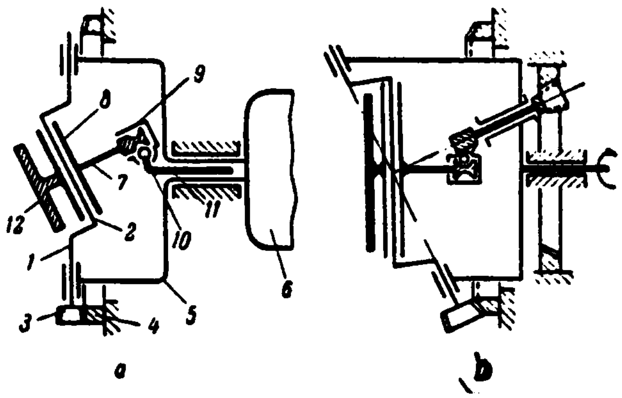

Fig. 57. Schematic diagram of the scanning device/equipment with a three-dimensional-mechanical converter: a) with the circular path of scanning; b) with the rotational-rotational trajectory of scanning.

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In the device/equipment examined the scanning platform completes rotary motion. In order to perform actuator with the nonrotating platform, to this device/equipment it suffices to add the special holding mechanism.

By a change in the relationships/ratios of the parameters of the mechanism examined it is possible to form/shape the trajectories of all types (having relationships/ratios parameters 2r<R, 2r=R, 2r>R). Fig. 58 presents the element/cell of the mechanism of a similar drive. During this performance of mechanism the trajectory of scanning differs somewhat from a rotary-rotary, moreover in this case

stock/rod besides rotary motion, completes also reciprocating motions.

Let us examine the basic kinematic dependences for the mechanism of such type for the general case, occurred in Fig. 58.

On the Z-shaped crankshaft is arranged/located on the rotating bushing the connecting rod finger/pin whose axis is perpendicular to the axis of inclined neck. In the circular annular groove in the upper part of the connecting rod finger/pin enters the wrist pin. The latter is arranged/located so that its axis does not interesect the axis of stock/rod, but it is located at a distance ϵ from it. The axis of the crank finger/pin passes through the point of intersection of the axis of cylinder and axis of inclined gang in the position of mechanism into v.m.t. [в.м.т. - upper dead center (UDC)] and n.m.t. [н.м.т. - bottom dead center (BDC)]. Wrist pin is connected with the connecting rod finger/pin with the aid of special shroud, in consequence of which the wrist pin during the rotation of the crankshaft can rotate around the connecting rod finger/pin and in this case rotate piston around its axis. In this mechanism in one revolution of crankshaft the piston is turned also for one revolution.

For determining the law of the motion of stock/rod Fig. 59

depicts the diagram of the given mechanism. During the construction of diagram as the basis is accepted the constant/invariable distance $BC=l$ between the middle of the centerline of wrist pin and the point of intersection of inclined neck with the axis of cylinder during the motion of mechanism.

The three-dimensional/space schematic of this mechanism (see Fig. 59) is carried out for four positions of the crankshaft: $\alpha=0°$, $\alpha'=90°$, $\alpha''=180°$, $\alpha'''=270°$.

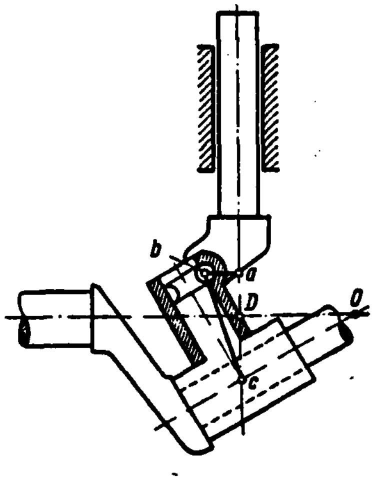

Fig. 58. Position of the mechanism, which creates the rotational-rotational trajectory of the motion of the scanning platform at $\alpha=0°$ (side view); av and vs - given motion rods.

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In the diagram the axis of crankshaft DO is arranged/located vertically, and the axis of cylinder DA - it is horizontal. The axis of inclined neck during the rotation of crankshaft forms conical surface with the apex/vertex at point O. Point C during the motion of mechanism describes a circle whose plane is perpendicular to the axis of crankshaft; point B is arranged/located on the surface of cylinder with a radius of e=AB, equal to the distance between centers of wrist pin and cylinder. Point A of link AB is located on the axis of cylinder and lies/rests together with point B at the plane,

perpendicular to the axis of the cylinder. The law of the motion of point A is the law of the motion of stock/rod. Cut aa'' is equal to course S of stock/rod.

As it was already noted, by the second component/link (besides component/link AB), which connects crankshaft with the stock/rod and not changing its size/dimension during the work of mechanism, is component/link BC. Thus, we obtain connection/communication of crankshaft DC with the stock/rod with the aid of two components/links of the constant length $AB=e$ and $BC=\sqrt{(r_1+r)^2+h^2}$, where r_1 - minimum radius of the annular groove of connecting rod finger/pin; r - radius of wrist pin; h - length of the axis of connecting rod finger/pin.

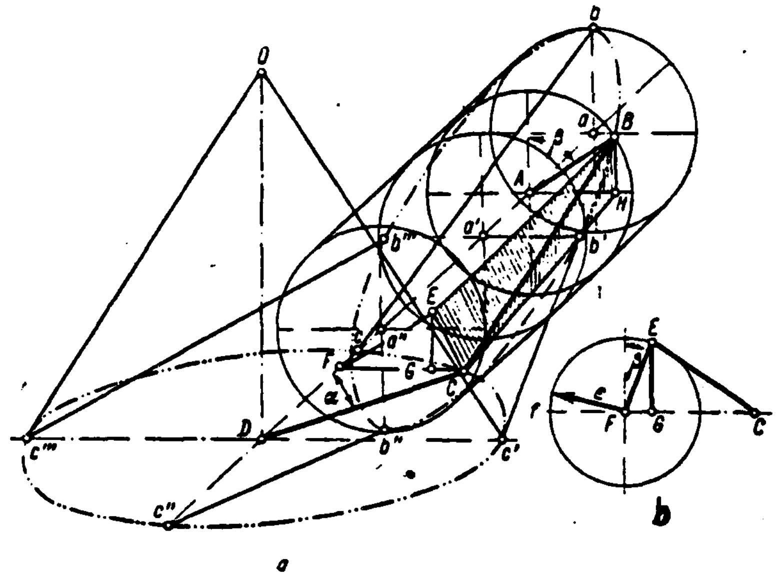

Fig. 59. Overall diagram of the given mechanism, which creates the rotational-rotational trajectory of the motion of the scanning platform.

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The flat/plane quadrangles abcD and $a''b''c''D$, which is located in the vertical plane, correspond to the position of mechanism at $\alpha=0°$ and $\alpha''=180°$. In the first case the stock/rod is located in the v.m.t., and the secondly - into the n.m.t.

The flat/plane quadrangles a'b'c'D and $a'b'''c'''D$, which are located in the horizontal plane, correspond to the position of the

mechanism at α'=90° and α'''=270°. Stock/rod in this case is located in the mid-position (Fig. 60).

Thus, the solution of the kinematics of this mechanism is reduced to the solution of the following three-dimensional-moving system of components/links. Point C of component/link BC evenly is circled (see Fig. 59); the position of radius DC is determined by angle α. Another end/lead cutting off BC (point B) moves over the surface of the cylinder of radius AB=e. Radius AB rotates around the axis of cylinder, being located in the plane, perpendicular to the axis of the cylinder (position of radius AB is determined by the value of angle β). The rotation of component/link AB has the specific law of a change in the angular velocity. The axis of cylinder lies/rests at the plane of rotation of point C; in this case cut BC completes complicated spatial motion.

Let us assume that to us is known the dependence β=f(α). From Fig. 59 we obtain the maximum distance of stock/rod from the axis of the shaft

$$DA_{\text{макс}} = R + \sqrt{l^2 - e^2} = \text{const} = K.$$

Piston travel

$$S = K - (R\cos\alpha + BE).$$

Points F and E lie/rest at plane FECG, therefore,

$$BE = \sqrt{(BC)^2 - (EC)^2}.$$

For determining of EC let us examine the projection of mechanism on which the axis of cylinder turns into the point (see Fig. 59):

$$(EC)^2 = (EG)^2 + (GC)^2;$$

$$EG = \varepsilon\cos\beta;\ GC = FC - FG;\ FC = R\sin\alpha;\ FG = \varepsilon\sin\beta;$$

$$(EC)^2 = \varepsilon^2\cos^2\beta + (R\sin\alpha - \varepsilon\sin\beta)^2.$$

We substitute the obtained values into the expression for S

$$S = K - R\cos\alpha - \sqrt{l^2 - \varepsilon^2\cos^2\beta - (R\sin\alpha - \varepsilon\sin\beta)^2}.$$

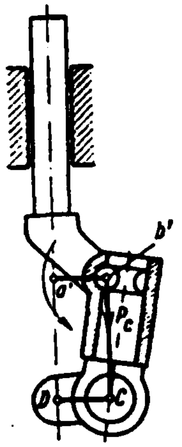

Fig. 60. Position of the mechanism, which creates a rotational trajectory, at α=90 and 270° (end elevation of drive shaft).

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The synchronous rotation of stock/rod and shaft occurs with such relationship/ratio of design parameters (e=R), with which the given component/link b'C is arranged/located in parallel to the axis of stock/rod at α=90° and α=270° (see Fig. 60). In the case of the synchronous rotation of components/links DC and a'b' the law of the motion of stock/rod can be obtained from the preceding/previous expression with the substitution in it β=α and e=R it will take the form

$$S = K - R\cos\alpha - \sqrt{l^2 - R^2\cos^2\alpha}.$$

The given three-dimensional/space diagram for the case of the synchronous rotation of stock/rod and shaft can be obtained from Fig.

59, if ϵ=R and β=α.

The author with the group of colleagues [1] developed the scanning device/equipment whose schematic diagram is given in Fig. 57b, and structural/design use and general view - in Fig. 61.

FOOTNOTE [1]. In the development of this device/equipment they participated by I. K. Mel'nichenko and O. I. Karyagin. ENDFOOTNOTE.

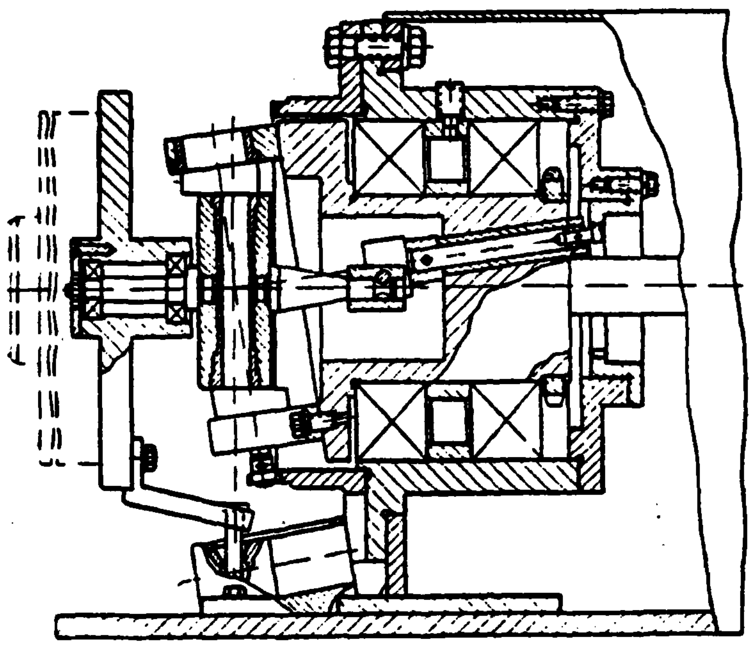

Fig. 61. Scanning device/equipment with the rotational-rotational trajectory of scanning.

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In this device/equipment the scanning platform completes spherical displacements relative to one fixed point. Because of this for the retention of this platform from the rotation can be used the special piston connection, moving in the motionless cylinder. In this device/equipment the stock/rod, rigidly connected with the scanning platform, is connected with the aid of the cylindrical telescopic joint with the cylindrical wrist pin. The latter is arranged/located perpendicularly to the axis of movable sustaining piston and can be turned relative to it to certain angle.

This mechanism of the retention of the scanning platform from the rotation makes it possible for it to complete any spherical displacements relative to fixed point.

For the formation of the divergence of electron beam in the cathode-ray tube of the block/module/unit, which reproduces image, are utilized four inductance pickups, established/installed after the scanning platform. These sensors are arranged/located at angle of 90° relative to each other and are connected in pairs. This mutual location of sensors allows determining any displacements of the scanning platform. The signals, obtained from each pair of sensors, are amplified and are supplied to the deflection coils of cathode-ray

tube. With the aid of these signals are realized the synchronous displacements of the scanning beam of the analyzer of image and electron beam in the cathode-ray tube of the synthesizer of image.

The scanning device/equipment developed in IAT realizes scanning along the rotational-rotational rosette trajectory with the relationship/ratio of the parameters 2r=R (see Fig. 1), the socket having 10 lobes/lugs, and full wave of scanning round field is 80 s. As the electric drive is used the electric motor DBS-YI, which rotates the scanning device/equipment through worm reducer (i=2000). On the scanning device/equipment can be established/installed the pyrometer of any operating principle (radiation, brightness or color).

Chapter 13.

Planetary and three-dimensional/ mechanisms, which realize displacement of scanning beam over the vibrational-rotational trajectory.

1. Cam and plane-crankshft scanning mechanisms.

In the devices/equipment of this type with the aid of the special mechanisms are realized the rotary and oscillatory displacements of scanning beam. Via the addition of these motions is formed/shaped the vibrational-rotational trajectory of scanning.

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In this section are examined several scanning devices/equipment in which are used different types of three-dimensional-bellows and mechanical converters of rotary motion into the reciprocating.

Examination let us begin from the mechanism, represented in Fig. 62a. The device/equipment of this mechanism is reduced to the following. With the aid of electric motor 2 is rotated housing 1, in which in the bearings is arranged/located shaft 3. On shaft 3 on

movable splined or cotter joint 5, is arranged/located cylinder 4, which has the inclined flat/plane gash in which is established/installed circular flat/plane washer 6. This washer has the cylindrical pin on which is established/installed scanning platform 8. Washer 6 is established/installed in such a way that its cylindrical pin is located in the hole of cylindrical finger/pin 7, arranged/located in housing 1. This installation of washer gives to it the possibility to complete three-dimensional/space displacements during the rotation of shaft 3 and connected with it with the aid of the splines cylinder 4. With these displacements type of washer 6 completes oscillatory, longitudinal and rotary displacements relative to housing 1.

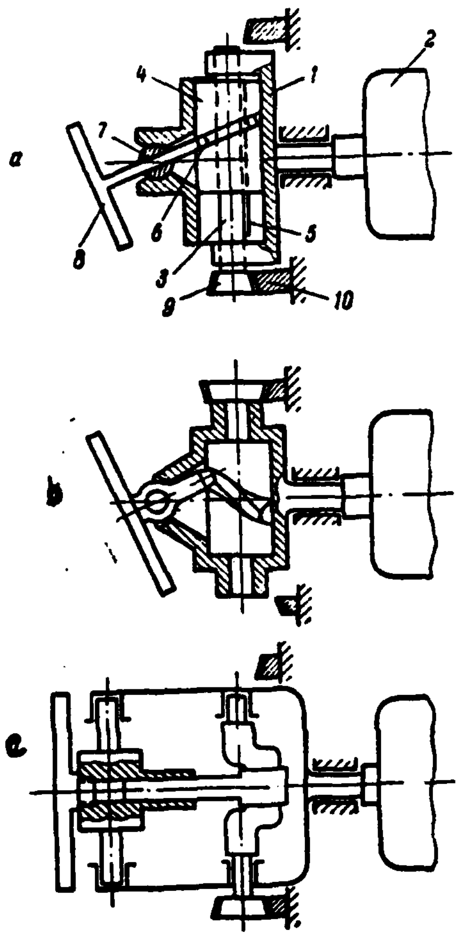

Fig. 62. Different types of the drives of the scanning platform, which accomplishes the vibrational-rotational trajectories of motion with the aid of the mechanism of the flat/plane wobble plate (a), three-dimensional/space cam gear (b), a flat-crank mechanism (c).

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For the creation of rotary motion on shaft 3 is rigidly

established/installed gear 9 which during the rotation of housing 1 is rolled on motionless gear 10. In this case platform 8 with the oscillatory motions simultaneously completes also rotary motion. The addition of these two motions forms/shapes the vibrational-rotational trajectory of scanning. Since the diameter of gear 9 many times of less than the diameter by gear 10, then is formed/shaped socket vibrational-rotational trajectory. When the axis of shaft 3 is perpendicular to the axis of drive shaft, is created vibrational-rotational trajectory with parameters $C=2R$ (see Fig. 1). By a change in the angle between axis 3 and axis it moves it is possible to obtain vibrational-rotational trajectory with relationships/ratios $C=R$, $C<R$, $C>R$ and $C=2R$ (see Fig. 1).

In the device/equipment examined the scanning platform during the motion along the trajectory of scanning realizes also certain rotation relative to its axis. However, the presence of this motion does not lead to the appearance of supplementary errors in the scanning, since sensing element established/installed on the platform has the axisymmetric character of sensitivity.

The advantage of this scanning device/equipment is the fact that it can be carried out by very small in comparison with other devices/equipment of this type, and deficiency/lack - high power losses to friction.

The scanning device/equipment of a similar operating principle is represented in Fig. 62b. The oscillatory motion of the scanning platform is realized in it with the aid of the three-dimensional/space cam gear and the roller of that established/installed on the same swaying yoke/arm on which is arranged/located the scanning platform. A deficiency/lack in the device/equipment is the large complexity of producing the specially shaped three-dimensional cam, and by advantage - broad band of a change in the trajectory of scanning with a change in the cam profile. In this device/equipment, as in preceding/previous, the scanning platform completes rotary motion together with the housing of mechanism.

Actuator of the scanning platform of this type can be carried out also on the diagram, depicted on Fig. 62c. Its device/equipment is analogous with that examined above, with the only difference that the the oscillatory motion of platform is created with the aid of a crank-plunger mechanism. A deficiency/lack in this device/equipment is the presence of telescopic mechanism as the basic load-bearing element which, on the basis of the creation of standard conditions of lubrication, must have large overall sizes. This requires the establishment of the second radial bearing for the rotating housing,

which causes the complication of the scanning system.

The use of a mechanism of this type is rational, when the mass, which accomplishes three-dimensional/space displacement, has comparatively low value.

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2. Three-dimensional-spherical scanning mechanism.

Operating principle. Let us examine the class of the scanning devices/equipment as basis of which are assumed three-dimensional/space spherical mechanisms. Examination let us begin from the mechanism, depicted on Fig. 63.

All givers of mechanism are arranged/located in housing 1, rotated by engine 2. In the bearings of the housing is located crankshaft 3, which has inclined neck. On this neck on the bearings is arranged/located bushing 4, on which is established/installed scanning platform 5. On the other side of bushing 4, is arranged/located pin 6 which is moved in guiding 7, established/installed on housing 1, and creates during the rotation of shaft 3 flat/plane oscillatory motion of yoke/arm 4-6. On the axis of the crankshaft 3 on one side is rigidly established/installed gear 8 which during the rotation of housing 1 is rolled on motionless gear 9 and makes it necessary to rotate shaft 3.

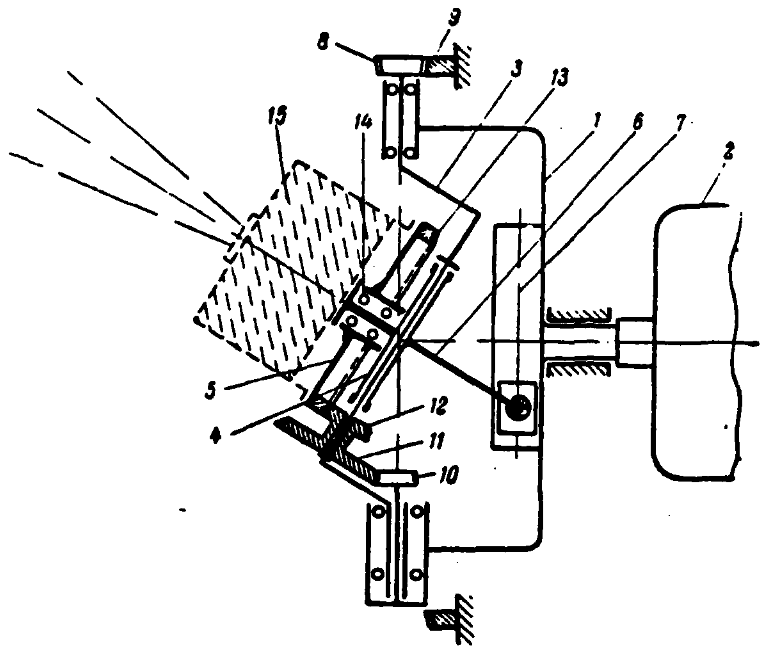

Fig. 63. Scanning device/equipment, created on the basis of a three-dimensional-spherical mechanism, with the retention of the scanning platform from the rotation.

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In view of the fact that the oscillatory motions of platform 5 are completed with the simultaneous rotary motion of housing 1, the photoelectric device/equipment, established/installed on the platform, will complete scanning the controllable/controlled/inspected region of space along an oscillatory-rotary trajectory.

So the diameter of gear 8 is many times of less than the diameter of gear 9, in one revolution of leading rocker shaft it completes d_9/d_8 oscillations and here is formed/shaped socket vibrational-rotational trajectory with a number of lobes/lugs d_9/d_8. If the drive of shaft 3 is carried out with the aid of the separate electric motor, then the device/equipment examined makes it possible to form/shape also the spiral trajectories of scanning.

It is necessary to note that in this scanning device/equipment as well as in the previously mechanisms of this type examined, in the case when the axis of crankshaft 3 is perpendicular to the axis of drive shaft, is formed/shaped socket trajectory with parameters C=2R (see Fig. 1). By the inclination/slope of the axis of shaft 3 to the axis of drive shaft it is possible to perform any type of trajectory.

In this device/equipment the scanning platform, rigidly established/installed on the yoke/arm, completes rotary motion. In order to give to it the zero rotational speed, on the elbowed, to shaft, to flywheel bushing and to the scanning platform is installed special serrated transmission 10, 11, 12, 13 (Fig. 63). This transmission rotates platform 5 during its scanning three-dimensional/space displacements to the reverse side relative to

the direction of rotation of drive motor 2. In this case the scanning platform is established/installed on the flywheel neck on the antifriction bearings 14, which gives to it the possibility to be pulled relative to rocker shaft under the effect of gear drive.

Stabilized platform 5 with the scanning displacements simultaneously completes even and rotation to certain angle relative to rocker shaft 4-6. However, this small rotation of focuser 15 and sensing element relative to axis (under the condition of their axial symmetry) does not introduce supplementary errors into the process of scanning.

Research of kinematics and dynamics. Basic kinematic and dynamic laws governing this mechanism are examined in the work of the author [1].

FOOTNOTE [1]. G. P. Katys. Investigation of kinematics and dynamics of three-dimensional/space mechanism. Coll. of the labor/works of MVTU [MBTY - Moscow Higher Technical School]. Department "Internal combustion engines". MVTU, 1955. ENDFOOTNOTE.

Below in the short form are given the kinematic and dynamic characteristics of this mechansim.

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Let us examine the most general case when the axis of crankshaft is inclined toward the axis of engine and the retention of yoke/arm from the rotation is realized with the aid of the cylindrical piston, moving in the supporting cylinder and connected with the yoke/arm with the aid of the cylindrical hinge joint with the telescopic joint (Fig. 64).

During the analysis of the characteristics of this scanning device/equipment for the simplification we consider that the general/common/total rotary motion of mechanism around the axis of electric drive is absent. The acceptance of this assumption is possible, since the angular velocity of rotary motion of the housing in the developed and considered/examined below scanning device/equipment has very low value (in several dozen times of less than the angular rate of rotation of crankshaft). Therefore the error, which appears from this assumption, is very small.

Kinematics. Let us examine the type of the mechanism, depicted on Fig. 64. During the conclusion/output of basic kinematic dependences were accepted the following designations:

α, ω - respectively angle of rotation and the angular velocity

of crankshaft; δ - angle of the slope of the axis of crankpin; β - angle of the slope of the axis of the cylinder of the sustaining piston relative to the axis of crankshaft; γ - angle between the plane of the axes of cylinder and shaft and the plane of axes OX and OZ yoke/arm; θ - variable angle of the slope of rocker shaft; b - distance OO_x.

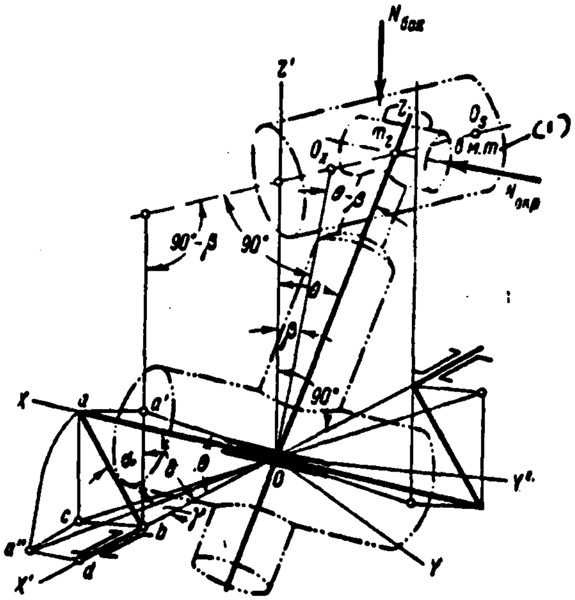

Fig. 64. Schematic of yoke scanning mechanism.

Key: (1). v.m.t.

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The directions of all angles are selected, on the basis of maximum simplification in the conclusion/output.

Let us determine the relationships/ratios of angles α, γ, δ and θ.

From triangles aOb and a'Ob we have:

$$\frac{a'b}{Ob} = \frac{ab}{Ob}\cos\alpha; \quad \operatorname{tg}\theta = -\operatorname{tg}\delta\cos\alpha;$$

consequently,

$$\theta = \operatorname{arctg}(-\operatorname{tg}\delta\cos\alpha). \qquad (1)$$

From triangles aOb and Oa" d we obtain

$$\frac{a''d}{a''O} = \frac{ab\sin\alpha}{aO};$$

hence

$$\sin\gamma = -\sin\alpha\sin\delta. \qquad (2)$$

Differentiating expression (1), we determine angular velocity and angular acceleration of the fluctation of yoke/arm in the plane of the axes of the cylinders:

$$\frac{d\theta}{dt} = \frac{\operatorname{tg}\delta \sin\alpha}{1 + \operatorname{tg}^2\delta\cos^2\alpha}\,\omega; \qquad (3)$$

$$\frac{d^2\theta}{dt^2} = \frac{\operatorname{tg}\delta\cos\alpha}{(1 + \operatorname{tg}^2\delta\cos^2\alpha)^2}\,\omega^2. \qquad (4)$$

During the secondary differentiation we throw/reject the terms, which contain $\operatorname{tg}^3\delta$, since at the in practice possible values of angle δ value $\operatorname{tg}^3\delta$ is very low.

Differentiating expression (2), we determine the angular velocity of the rotation of the yoke/arm around axis OZ:

$$\frac{d\gamma}{dt} = -\frac{\sin\delta\cos\alpha}{\sqrt{1 - \sin^2\delta\cos^2\alpha}}\,\omega.$$

In this position of mechanism the path of the sustaining piston is determined as follows:

$$S = x_0 - x,$$

where

$$x_0 = b\operatorname{tg}(\delta - \beta);$$

$$x = b\operatorname{tg}(-\theta - \beta).$$

From Fig. 64 it follows that $O_xO_z = x_0$; $O_xm_z = x$; $O_zm_z = S$.

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Differentiating the preceding/previous expression, we find speed and acceleration of the sustaining piston:

$$v=-\frac{dx}{dt}=\frac{b}{\cos^2(-\theta-\beta)}\cdot\frac{d\theta}{dt}; \tag{6}$$

$$j=\frac{d^2S}{dt^2}=-\frac{d^2x}{dt^2}=$$

$$=\frac{b}{\cos^2(-\theta-\beta)}\cdot\left[\frac{d^2\theta}{dt^2}-2\,\mathrm{tg}(-\theta-\beta)\left(\frac{d\theta}{dt}\right)^2\right]. \tag{7}$$

From the analysis of kinematics it is evident that this mechanism in n.m.t. has an acceleration $j_{н.м.т.}$ somewhat larger than acceleration in v.m.t. $j_{в.м.т.}$ (Fig. 65), in contrast to the mechanism with the axis of the cylinder of the sustaining piston, parallel to the axis of the crankshaft, which has $j_{н.м.т.}=j_{в.м.т.}$. The displaced location curved S in Fig. 65 is explained by the fact that during the conclusion/output was accepted $S=x_0-x$.

Dynamics. Let us determine the three-dimensional/space directed inertia forces, which act on different components/links of the scanning mechanism in question.

For determining three-dimensional/space directed resultant of the inertia pressure of the sustaining piston on the guiding cylinder we expand it to two components $N_{бок}$ (see Fig. 64), that lies at the plane of the fluctation of yoke/arm, and $N_{окр}$, located in perpendicular plane. Then both components are determined separately.

Effort/force $N_{бок}$ is determined from the geometry of the

mechanism:

$$N_{бок} = \frac{P_{н}}{\mathrm{ctg}(-\theta - \beta)}, \qquad (8)$$

where $P_{н}$ - effort/force, which acts along the axis of the sustaining piston and which is determining by the weight of piston and by the kinematics of its motion.

The inertial moment, which appears from the rotary motions of wrist pin, in view of its insignificant value we do not consider.

In order to determine effort/force $N_{окр}$, it is necessary to examine the dynamics of the motion of yoke/arm.

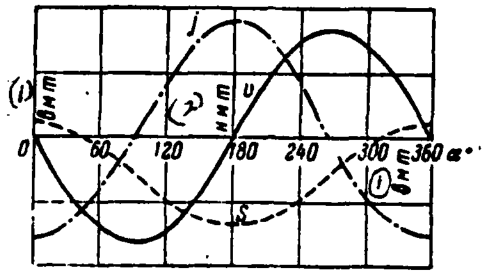

Fig. 65. Change in way of S, speed v and accelerating j the sustaining piston of the yoke scanning mechanism.

Key: (1). v.m.t. (2). n.m.t.

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Yoke/arm completes complicated oscillating motion around the fixed center of gravity (point O); therefore the solution of its dynamics can be carried out with the aid of the equations of dynamic moments/torques (Euler equations).

For solving the dynamics the yokes/arms are selected fixed coordinate system OX', OY', OZ' (see Fig. 64) and the system of coordinates OX, OY, OZ whose axes are rocker shafts and complete together with it the appropriate motions. For this case of the Euler equation they take the following form:

$$
\left.
\begin{aligned}
I_x \frac{d\omega_x}{dt} + (I_z - I_y)\,\omega_y\omega_z &= \Sigma M_x,\\
I_y \frac{d\omega_y}{dt} + (I_x - I_z)\,\omega_z\omega_x &= \Sigma M_y,\\
I_z \frac{d\omega_z}{dt} + (I_y - I_x)\,\omega_x\omega_y &= \Sigma M_z,
\end{aligned}
\right\} \qquad (9)
$$

where I_x, I_y and I_z - moments of the inertia of yoke/arm with those established/installed on it by the scanning platform and optics relative to the appropriate principal axes OX, OY, OZ; ΣM_x; ΣM_y and ΣM_z - total dynamic moments with respect to the appropriate principal OX, OY, and OZ (movable) rocker shafts.

After the substitution of the corresponding parameters we obtain angular velocities and accelerations for a special case, necessary for solving the Euler equations:

$$
\left.
\begin{aligned}
\omega_x &= \frac{d\theta}{dt}\sin\gamma; \quad \frac{d\omega_x}{dt} = \frac{d^2\theta}{dt^2}\sin\gamma + \frac{d\theta}{dt}\cdot\frac{d\gamma}{dt}\cos\alpha,\\
\omega_y &= \frac{d\theta}{dt}\cos\gamma; \quad \frac{d\omega_y}{dt} = \frac{d^2\theta}{dt^2}\cos\gamma - \frac{d\theta}{dt}\cdot\frac{d\gamma}{dt}\sin\gamma,\\
\omega_z &= \frac{d\gamma}{dt}; \quad \frac{d\omega_z}{dt} = \frac{d^2\gamma}{dt^2}.
\end{aligned}
\right\} \qquad (10)
$$

Let us compose momental equation relative to the axis of inclined crankpin taking into account dynamic moment/torque ΣM_x and let us determine $N_{окр}$:

$$
I_x \frac{d\omega_x}{dt} + (I_z - I_y)\,\omega_y\omega_z = N_{бок} r \sin\gamma + N_{окр} r \cos\gamma, \qquad (11)
$$

where r - distance from working point $N_{бок}$ and $N_{окр}$ to point O (see Fig. 64).

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For the uniform rotation of the shaft of this mechanism to it it is necessary to apply certain variable torque M_j, required for overcoming the forces of inertia of all moving/driving motion rods. In order to determine inertial moment $M_j = 1/\omega \cdot dT/dt$, we find energy T, necessary at each moment/torque for rotating the shaft of this mechanism:

$$T = \frac{m_{пор}}{2} v_a^2 + I_x \frac{\omega_x^2}{2} + I_y \frac{\omega_y^2}{2} + I_z \frac{\omega_z^2}{2} + I_{пал} \frac{d\theta}{dt},$$

where $m_{пор}$ - mass of piston and finger/pin; $I_{пал}$ - moment of the inertia of finger/pin.

In this formula the first term is the kinetic translational energy of the sustaining piston, the second, third and fourth terms - energy, required for the fluctation of yoke/arm with the fastened/strengthened to it scanning device/equipment relative to three axes OX', OY' and OZ'.

By the fifth term, which expresses the kinetic energy, necessary for the rotation of wrist pin around its axis, it is disregarded due to the smallness.

Let us determine the inertial moment of yoke mechanism;

$$M_j = \frac{1}{\omega}\left(m_{\text{поп}} v_a j_a + I_x\omega_x \frac{d\omega_x}{dt} + I_y\omega_y \frac{d\omega_y}{dt} + I_z\omega_z \frac{d\omega_z}{dt}\right), \quad (12)$$

where j_a - acceleration of the sustaining piston.

Unstable moments, which appear during the motion of mechanism, are composed from unstable moments, created during the motion of yoke/arm and sustaining piston. The unbalanced efforts/forces of mechanism are determined by the unbalanced efforts/forces of piston group.

During the determination of unstable moments of yoke/arm each of its dynamic moments/torques, referred to moving axes (see formula (9) and Fig. 64), was designed on the fixed axes of coordinates. For this were determined the corresponding cosines of the angles of design. Further via the addition of the corresponding moments with respect to the similar/analogous fixed axes OX', OY' and OZ' obtained unstable moments, applied to the housing of mechanism.

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For determining unstable moments, appearing during the motion of yoke/arm and applied to the housing of mechanism, each of these moments/torques we project/design for fixed axes X'Y'Z'. We obtain $M_{X'x}, M_{X'y}, M_{X'z}$ - moments/torques around fixed axis OX' from dynamic

moments/torques M_X; M_Y; M_Z and so on respectively:

$$M_{X'X} = M_X \cdot a_{X'X};$$
$$M_{X'Y} = M_Y \cdot a_{X'Y};$$
$$M_{X'Z} = M_Z \cdot a_{X'Z};$$
$$M_{Y'X} = M_X \cdot a_{Y'X};$$
$$M_{Y'Y} = M_Y \cdot a_{Y'Y};$$
$$M_{Y'Z} = M_Z \cdot a_{Y'Z};$$
$$M_{Z'X} = M_X \cdot a_{Z'X};$$
$$M_{Z'Y} = M_Y \cdot a_{Z'Y};$$
$$M_{Z'Z} = M_Z \cdot a_{Z'Z}.$$

The cosines of the angles between the axes of coordinates X', Y', Z' and X, Y, Z according to the Euler equation are determined by the following formulas:

$$a_{X'X} = \cos\psi\cos\varphi - \sin\psi\sin\varphi\cos\theta;$$
$$a_{Y'X} = \sin\psi\cos\varphi + \cos\psi\sin\varphi\cos\theta;$$
$$a_{Z'X} = \sin\varphi\sin\theta;$$
$$a_{X'Y} = -\cos\psi\sin\varphi - \sin\psi\cos\varphi\cos\theta;$$
$$a_{Y'Y} = -\sin\psi\sin\varphi + \cos\psi\cos\varphi\cos\theta;$$
$$a_{Z'Y} = \cos\varphi\sin\theta;$$
$$a_{X'Z} = \sin\psi\sin\theta;$$
$$a_{Y'Z} = -\cos\psi\sin\theta;$$
$$a_{Z'Z} = \cos\theta.$$

After the necessary substitutions we obtain the following expressions:

$$a_{X'X} = \cos\delta;$$
$$a_{Y'X} = \sin\gamma;$$
$$a_{Z'X} = -\cos\gamma\sin\theta;$$
$$a_{X'Y} = -\sin\gamma\cos\theta;$$
$$a_{Y'Y} = \cos\gamma;$$
$$a_{Z'Y} = \sin\gamma\sin\theta;$$
$$a_{X'Z} = \sin\theta;$$
$$a_{Y'Z} = 0;$$
$$a_{Z'Z} = \cos\theta.$$

Summarizing the appropriate moments/torques around the similar/analogous axes, we obtain:

$$M'_{X'} = M_{X'X} + M_{X'Y} + M_{X'Z}$$
$$M'_{Y'} = M_{Y'X} + M_{Y'Y} + M_{Y'Z};$$
$$M'_{Z'} = M_{Z'X} + M_{Z'Y} + M_{Z'Z}.$$

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These unstable moments are applied to the rotating housing of the scanning mechanism.

During the determination of the unbalanced efforts/forces, which act on the housing of the scanning mechanism during the motions of the sustaining piston, the acceleration of the latter, expressed by rapidly converging series, we analytically expand to two harmonics. After conversion the unbalanced efforts/forces and moments/torques from each harmonic of acceleration were determined separately.

The resolution of the acceleration of piston into two harmonics only simplifies the analytical definition of the steadiness of the given mechanism and, as it was proved by calculation, has the completely sufficient accuracy:

$$j = A_I b\omega^2 \cos\alpha + A_{II} b\omega^2 \cos 2\alpha \qquad (13)$$

For determining the constants A_I and A_{II} we find the values of accelerations through formula (7) at α=0, 90 and 180° and equate to their corresponding coefficients of the harmonics of accelerations in the dependence on the relationship/ratio of harmonics in the given points:

at α=0°

$$(-\theta-\beta)_0 = \delta-\beta; \quad \frac{d\theta}{dt} = 0; \quad \frac{d^2\theta}{dt^2} \approx \operatorname{tg}\delta;$$

$$j = \frac{b}{\cos^2(\delta-\beta)} \operatorname{tg}\delta = (A_I - A_{II}) b\omega^2;$$

at α=90°

$$(-\theta-\beta)_{90^\circ} = \beta; \quad \frac{d\theta}{dt} = \operatorname{tg}\delta; \quad \frac{d^2\theta}{dt} = 0;$$

$$j_{90^\circ} = \frac{2b\sin(-\theta-\beta)}{\cos^3\beta} \operatorname{tg}^2\delta = A_{II} b\omega^2;$$

at α=180°

$$(-\theta-\beta)_{180^\circ} = -\delta-\beta; \quad \frac{d\theta}{dt} = \theta; \quad \frac{d^2\theta}{dt^2} \approx \operatorname{tg}\delta;$$

$$j_{180^\circ} = \frac{b}{\cos^2(-\delta-\beta)} \operatorname{tg}\delta\omega^2 = (-A_I - A_{II}) b\omega^2.$$

From the equations given above we determine value A_I and A_{II}:

$$\Delta_{\mathrm{I}} = \left[\frac{\operatorname{tg}\delta}{\cos^3(\delta-\beta)} + \frac{2\sin\beta\operatorname{tg}^2\delta}{\cos^3\beta}\right].$$

$$\Delta_{\mathrm{II}} = \left[\frac{2\sin\beta\cdot\operatorname{tg}^2\beta}{\cos^3\beta}\right]. \tag{14}$$

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These two harmonic components of inertia force act on the rotating housing of the scanning mechanism in the direction of the axis of supporting cylinder.

At the high rates of scanning it is necessary to consider the presence of the uniform rotary motion of the housing of device/equipment. With this it is necessary to consider in essence the emergence of the Coriolis acceleration and efforts/forces, which appear in the parts of mechanism with their radial displacement in the rotating housing. This first of all relates to the oscillating yoke/arm and to the parts of the moving bearing pulley. In this case it should be noted that the introduction of the corresponding corrections to the formulas examined leads to their considerable complication.

Experimental investigation. For the oscillographic checking of the derived dependences was designed and prepared the dynamic model of the basic node/unit of the scanning mechanism examined.

The model of the swaying yoke/arm has the following parameters: $\alpha=12°$, $\beta=8°$, b=146 mm; S=62 mm. The crankshaft of model has the inclined neck on which is established/installed the swaying yoke/arm, connected with the aid of the telescopic articulation with the wrist pin of the sustaining piston. The yoke/arm, made by dismountable/release along the axis of inclined neck journal, is established/installed on the slide bearings. Wrist pin is fixed in the axial direction. Piston is moved in the supporting cylinder, equipped with three measuring plates, arranged/located at angle of 120° one relative to another.

The measurement of the three-dimensional/space directed pressure of piston on the cylinder was made with the aid of that specially developed measuring device/equipment (Fig. 66).

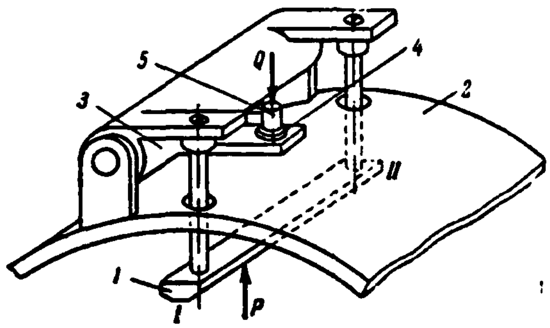

Fig. 66. The sensor, which is determining the values of the effort/force the point of application of which can be moved along line I-II.

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It is installed on cylinder 2 in the form of plate 1, connected with special lever 3, 4, which receives the pressure of piston and which transmits it to piezoelectric quartz crystal sensor 5. Reference piston is moved on three plates, which replace cylindrical surface. Device/equipment is made in such a way that independent of the place of the application of pressure along the length of plate its value is transferred to the sensor without the distortion.

During the experimental investigation were utilized the piezoelectric quartz crystal sensors which were placed into three measuring devices. During the preparation for experiment the position

of measuring plates was regulated to such state when during the slow rotation of the shaft of mechanism sensors ceased to show any pressure on the plate. This testified about the correctness of the geometric form of the cylinder, formed by three measuring plates.

On the derived dynamic dependences for the model were determined the laws governing the components of the resultant of piston thrust on supporting cylinder ($N_{бок}$ and $N_{окр}$). According to these components were determined efforts/forces N_{I}, N_{II} and N_{III}, which affect three measuring plates.

The efforts/forces, determined by oscillography and depicted on Fig. 67 by broken lines, are close in the value to the theoretically specific efforts/forces (shown by solid lines) and, therefore, confirm the correctness of the method of calculation of the dynamics of this scanning mechanism proposed.

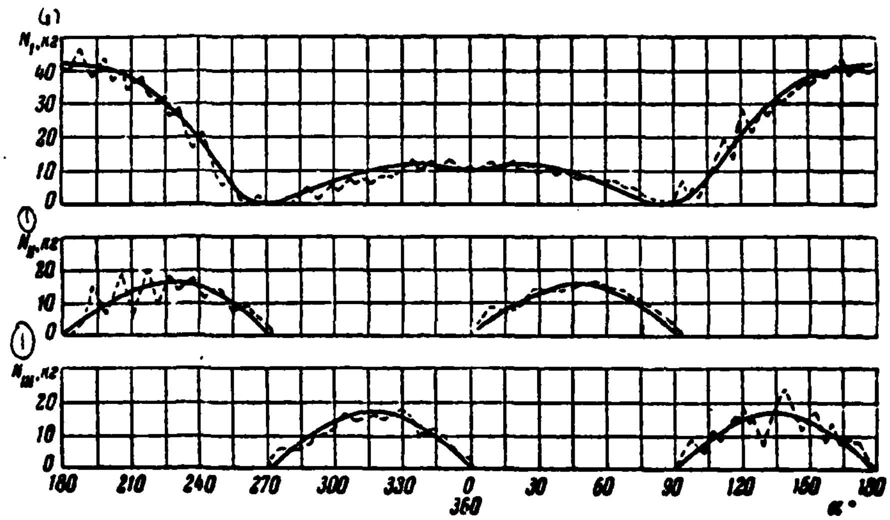

Fig. 67. Lateral forces from the effect of the sustaining piston on the wall of cylinder in the yoke scanning mechanism.

Key: (1). kg.

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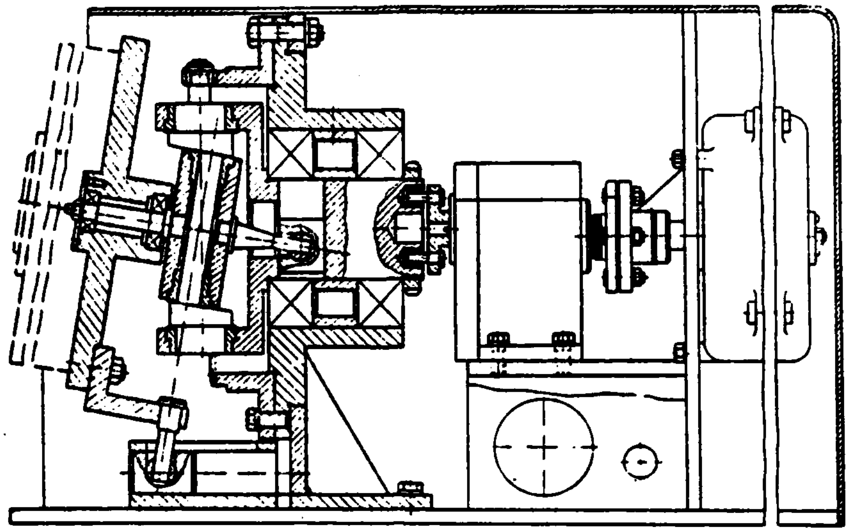

Fig. 68. Scanning device/equipment with vibrational-rotational socket trajectory.

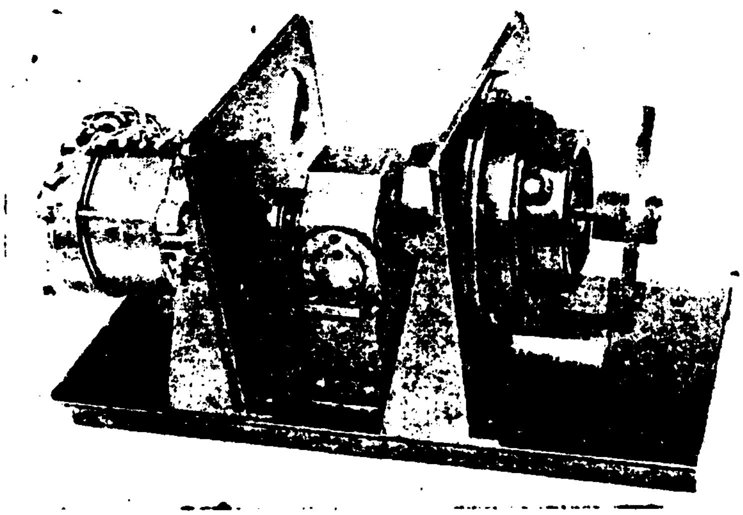

Fig. 69. General view of scanning device/equipment, represented in Fig. 68.

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On the basis of the results of theoretical and experimental studies presented above of the diverse variants of the scanning mechanism examined in IAT by the author with the group of colleagues[1] is developed and is prepared the scanning device/equipment, represented in Fig. 68.

FOOTNOTE: [1] I. K. Mel'nichenko and O. I. Karyagin participated in the work. ENDFOOTNOTE.

It has a basic schematic similar to that shown in Fig. 63, with the only difference being that in it is used another method of the retention of the scanning platform from the rotation. In this device/equipment the scanning platform completes spherical motion; therefore for its retention from the rotation can be used the same dual cylindrical hinge joint with the plastic connection, which is used for the creation of the flat/plane oscillatory motions of the yoke/arm of mechanism. The design concept of the parts of device/equipment is clear from Fig. 69.

Shaping of the signals of synchronization, necessary with

reconstruction of image, is realized with the aid of the inductance pickups. For the synchronization of the motions of the scanning platform and the electron beam in the cathode-ray tube are used four coils, arranged/located relative to platform in the manner that it is shown in Fig. 70a.

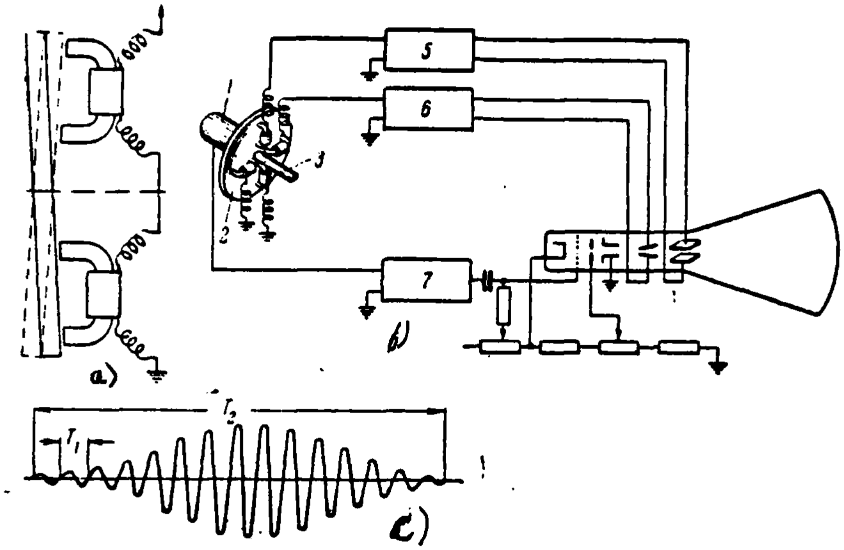

Fig. 70. Fundamental synchronizing circuit of the motions of the optical scanning beam and the electron beam in the cathode-ray tube of the synthesizer of the image: 1 - sensing element; 2 - scanning mirror; 3 - shaft of electric motor; 5, 6, 7 - amplifiers.

T_1 - period of one complete oscillatory motion of the scanning platform; T_6 - full wave of scanning.

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The cores of coils are permanent magnets; therefore with the displacements of metallic platform in the coils appear the electrical signals which are utilized for the synchronization of scannings/sweeps in the network element, which analyzes image, and

the element/cell, which synthesizes image.

The electrical signal, which appears in one pair of coils, is represented in Fig. 70c. This signal characterizes the kinematics of the motion of the zone of platform, adjacent to the specific pair of the coils of synchronization.

General/common/total electrical synchronizing circuit is represented in Fig. 70b. Signals from the coils after amplification are supplied to the deflector plates of cathode-ray tube, and its cathode enters signal from sensing element.

The scanning device/equipment realizes a vibrational-rotational socket trajectory with the relationship/ratio of parameters C=2R (see Fig. 1); in this case a number of lobes/lugs of socket is equal to 10; total period T of scanning it is 40 s.

The servo system, made on the basis of a three-dimensional-spherical mechanism. On the basis of spherical scanning mechanism examined above can be created also servo scanning device/equipment [70], represented in Fig. 71.

The principle of its action is reduced to the following. On inclined crankpin on the bearing is arranged/located the yoke/arm on

which is established/installed the telescope with the follower. The optical axis of telescope, the axis of inclined neck and the axis of crankshaft intersect at the central point of mechanism, because of this in any position latter the axis of the telescope is arranged/located along a radius of the sphere whose center is in the center of mechanism.

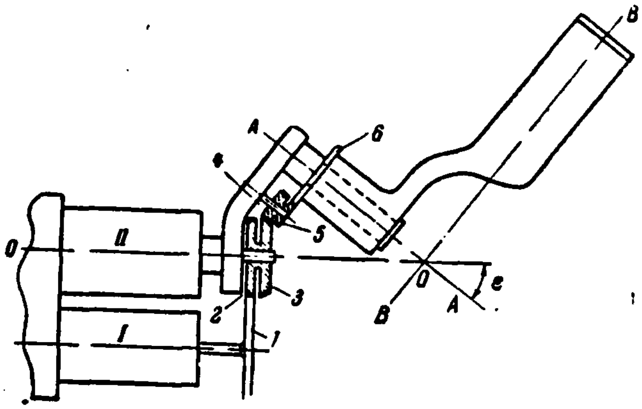

Fig. 71. Execution of the drive of telescope for its independent inclination/slope relative to two mutually perpendicular axes.

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So that the telescope could continuously follow the heavenly body, on the spherical mechanism are established/installed two electric motors, on which are given command from the servo system. Engine I realizes rotation of telescope relative to axis A-A of inclined crankpin, while engine II - turn of entire system relative to axis O-O. This telescope can follow any point of the spherical ring whose width grows/rises with an increase in the angle ϵ.

In order to divide effect from engines of the I and II on the angular position telescope, the drive of telescope from engine I is made through a carrier-planetary gear mechanism whose

device/equipment is reduced to the following. On axis O-O are freely arranged/located two gears 2 and 3, moreover the first cylindrical, and second conical. Gear 2 is articulated with gear 1, established/installed on the axis of electric motor I. Bevel gear 3 is articulated with bevel gear 4, freely established/installed on the axis on the guide of telescope. With the bevel gear is rigidly connected spur gear 5 which is articulated with gear 6, established/installed directly on the housing of telescope. This mechanism with the small angle ϵ and the equality of a number of teeth on gears 3 and 6 allows during the rotation of engine the II and motionless engine of the I to have almost motionless a projection of axis B-B of telescope on the plane, perpendicular to axis O-O. This phenomenon in the case of flat/plane planetary train bears the name "Fergusson paradox". In this case occurs only a change in the angular position of telescope in plane OOB. On the contrary, during the rotation of engine the I and motionless engine II occurs a change in the angular position of the projection of axis B-B of telescope on the plane, perpendicular to axis O-O. Thus, with the aid of this device/equipment it is represented possible from electric motors I and II to move telescope in two almost mutually perpendicular directions.

Telescope has the follower which provides tracking the selected heavenly body. As the follower can be established/installed any of

the III photoelectronic or optical-mechanical servo scanning devices/equipment examined in section.

Combination of three such tracking telescopes can be used in astronavigational system [70], intended for generating the signal of the correction of position, object on the position of three heavenly bodies - reference points. The operating principle of this astronavigational system is reduced to the following (Fig. 72).

Astronavigational system consists of two systems: the system, which ensures the motion of object along the predetermined trajectory, and the orientation system of object of the space.

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Both systems have the general/common/total complex of sensing elements, made in the form of three telescopes with the followers. Telescopes follow the selected three heavenly bodies, moreover the optical axes of telescopes intersect at one point. This makes it possible with simple means to conduct the measurement of the angles between the three-dimensional/space moving axes of telescopes. For this the telescopes are established/installed on the special mechanisms, which make it possible to move telescopes so that their axes are arranged/located along radii of one and the same sphere. In

the system are measured three angles α, β and γ between the optical axes of the telescopes which determine the location of object in the space.

If the heavenly bodies, accepted as the reference points, are selected so that the distance of them can be considered final, then from Fig. 73 it is possible to obtain the following dependences.

Let us examine triangles OCB, OAC, OAB, we obtain:

$$\text{(1) из } \triangle OCB\ CB^2 = OC^2 + OB^2 - 2OC \cdot OB \cdot \cos\beta;$$
$$\text{(1) из } \triangle OAC\ AC^2 = OA^2 + OC^2 - 2OA \cdot OC \cdot \cos\alpha;$$
$$\text{(1) из } \triangle OAB\ AB^2 = OA^2 + OB^2 - 2OA \cdot OB \cdot \cos\gamma;$$

Key: (1). from.

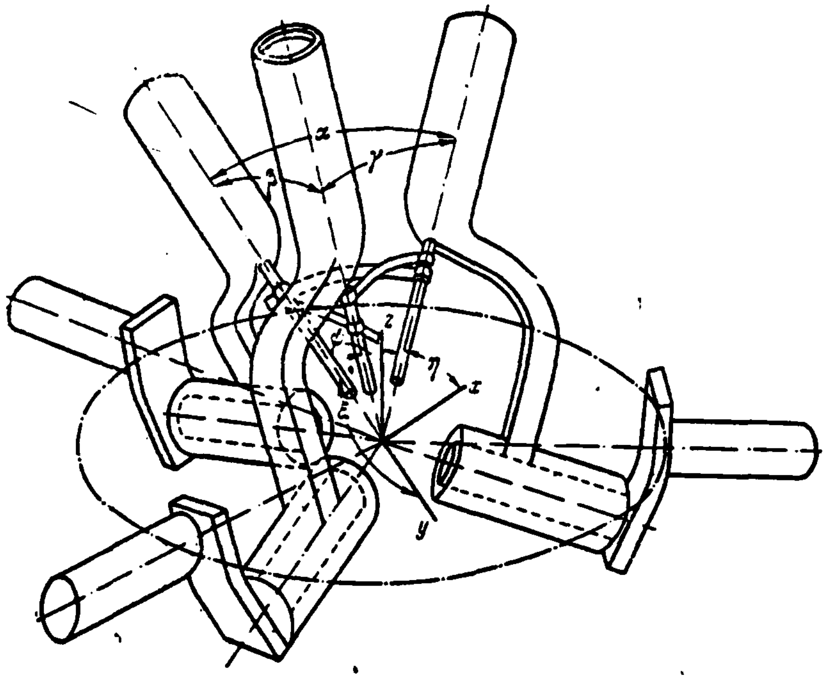

Fig. 72. Schematic of the astronavigational system, which realizes an orientation on three heavenly bodies.

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The distances between heavenly bodies AB, AC, CB change according to the previously known law (in the particular case they can be constant). Angles α, β, γ are determined by direct measurement. Thus, we have a system of three equations with three unknowns. Solving this system of equations, it is possible to determine the distances between the heavenly bodies and the object. As a result of the fact that the flight trajectory is previously

known, known and the laws of a change in the angles α_0, β_0, γ_0 in the function of time.

The angles $\alpha_0(t)$, $\beta_0(t)$, $\gamma_0(t)$, which are determining the assigned optimum trajectory, are introduced into the storage unit of program unit. The angles, measured between the optical axes of telescopes α, β, γ, are compared with the angles α_0, β_0, γ_0 for one and the same moment/torque of time. The signals of error $\Delta\alpha$, $\Delta\beta$, $\Delta\gamma$ enter the shaping unit of commands/crews, which taking into account the orientation of the axes of object in the space realizes an effect on it.

In the orientation system are measured the angles η, ζ, ψ between the optical axes of telescopes and three mutually perpendicular axes, rigidly connected with the object. These angles uniquely determine the orientation of object in the space. The assigned orientation of object (i.e. the angles between the appropriate axes x, y and z) is introduced into the storage unit of program unit. Angles η, ζ and ψ are compared with the angles η_0, ζ_0 and ψ_0, given by program unit. The error signals $\Delta\eta$, $\Delta\zeta$ and $\Delta\psi$ enter the shaping unit of commands/crews, which issues command/crew to the development of object to the assigned position.

Sensing elements of the system in question, as already

mentioned, are three telescopes with the servo systems. All three telescopes are made equally. For their drive are used three spherical mechanisms of the "wobble plate", in which on inclined crankpins are established/installed the telescopes (see Fig. 72). In this case the optical axis of each of them is perpendicular to the axis of inclined crankpin. This installation of telescopes on three elements/cells of the three-dimensional/space spherical mechanisms, which have the combined (common) central point of sphere, makes it possible to carry out an intersection of the optical axes of all three telescopes at one point. This also gives the possibility to keep constant the point of intersection of axes with any three-dimensional/space displacement of the axis of each of the telescopes.

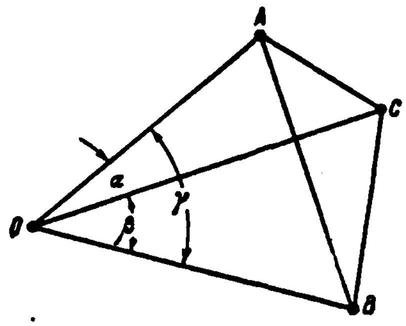

Fig. 73. Mutual location of three heavenly bodies - reference points.

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The presence of the common combined point of the optical axes of three telescopes makes it possible to considerably simplify the measurement of solid angles between the axes of telescopes with their displacement. In this case the axis of each telescope is arranged/located along a radius of sphere. Thus, the axes of any pair of telescopes in this case are arranged/located in one plane, which gives the possibility to measure the three-dimensional/space changing angles between the axes of telescopes according to the appropriate plane angles, and this measurement can be made by comparatively simple equipment, also, with the sufficiently high accuracy.

For measuring the angles in this device/equipment, in particular, can be used the pulse photoelectronic sensors, examined

below.

During the location of telescopes on the axes of inclined necks they, on the basis of the design considerations, can be displaced up to certain distance relative to the theoretical axes, passing through point O of the combined spherical mechanism, but they must be compulsorily to them parallel (error, which appears in this case, has negligible value). However, the axes of the goniometric rods, rigidly connected with the telescopes, must converge at the central point O of spherical mechanism.

Let us examine the device/equipment of the goniometric sensors, determining the mutual displacement of three telescopes relative to each other and relative to fixed axes x, y, z, connected with the housing. For this can be used the devices/equipment of different operating principles. Is examined below one of the possible versions of angular movement transducer.

The mutually moving parts of this sensor move over special guides, moreover so that the measurement of angle it would be possible to carry out in any position of both of telescopes, part of sensor established/installed on telescopes on the rotating bushings.

For measuring the angles between two telescopes it is possible

to use the raster method whose essence is reduced to the following. The construction/design of telescopes is made so that the continuations of rods intersect at one point (Fig. 74). With rod of one of the telescopes with the aid of the sleeve is connected the glass plate, made in the form of the element/çell of ring. On this plate through the equal angular gaps/intervals they are plotted/applied opaque primes, moreover the width of gaps/intervals is equal to the width of primes. With the rod of the second telescope is connected a small plate with the same primes. The passing through lattices pencil of rays from the light source falls on the photocell, established/installed on the first (long) glass plate (Fig. 74b). During the shift of lattices relative to each other the intensity of the luminous flux, which falls to the photocell, periodically are changed from 0 to maximum. The extent of movement can be determined according to a number of impulses/momenta/pulses.

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This can be carried out, supplying, for example, voltage from the output of amplifier to the winding of the electromagnetic relay, designed in such a way that it is closed at point a it is broken at point b (Fig. 74c). In this case in the relay circuit are created voltage surges which are differentiated and are supplied to the pulse counter. Knowing a radius of lattices, it is possible to determine

the angular displacement of telescopes. The sensitivity of device/equipment is determined by a number of primes of lattice per unit of length and it reaches 2.5 μ, which, for example, with a radius of 20 cm gives angular sensitivity 2.5".

The device/equipment examined makes it possible to determine the amount of shift without the determination of its direction. For determining the direction of shift it is possible to use the small lattice, which consists of two parts, shifted by one relative to another half-mark (Fig. 74d). Passing through the lattice, beam of light after reflection from the faces of prism falls on photocells 1 and 2. The phases of the photo currents of the first and second photocells are shifted on 90°, which makes it possible to judge the direction of displacement. This device/equipment gives the possibility to determine the total value of angular displacements when occurs certain number of recurrently forward motions as a result of which the telescope occupies new position.

For determining the orientation of the axes of object in the space with the aid of the analogous goniometric devices/equipment are determined the angles between axes x, y and z of object and axes of telescopes.

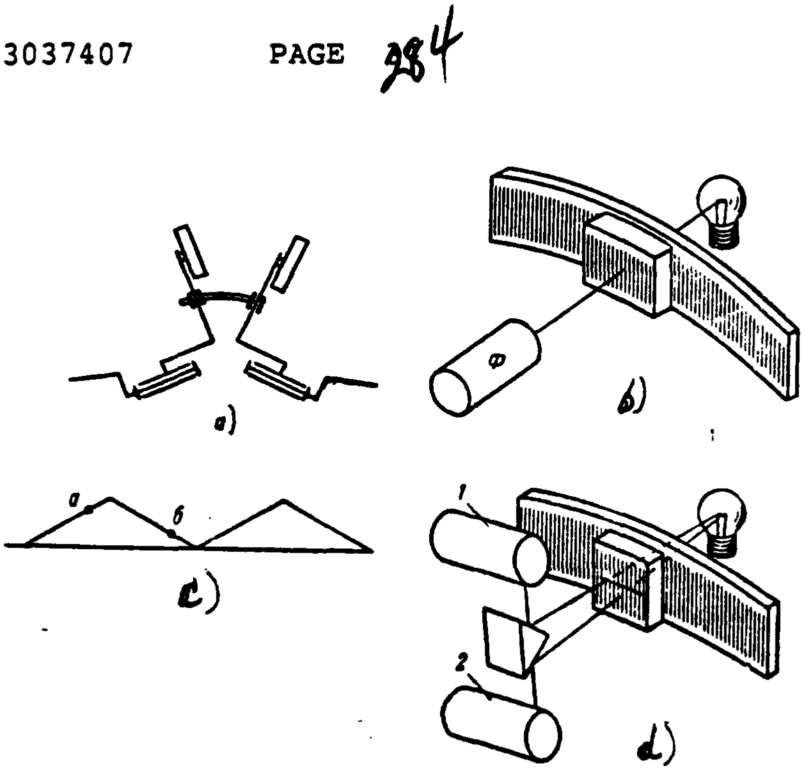

Fig. 74. Device/equipment, intended for measuring the angles of the mutual inclination/slope of the axes of three telescopes.

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The system of the telescopes examined, established/installed on three spherical mechanisms with the combined central point (and the set of the corresponding goniometric devices/equipment), is operational only in the specific region of the mutual displacements of telescopes. Therefore, during the selection of three heavenly body-reference points and the trajectory calculation must be determined the ranges of the angles of the mutual displacement of the

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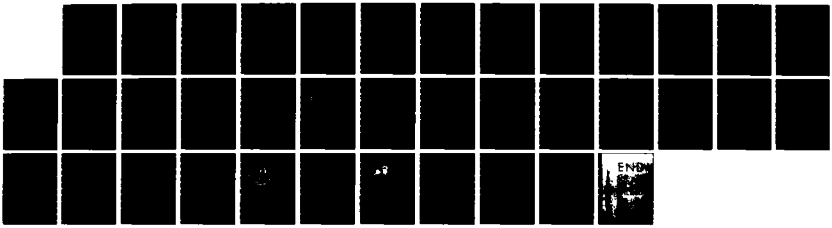

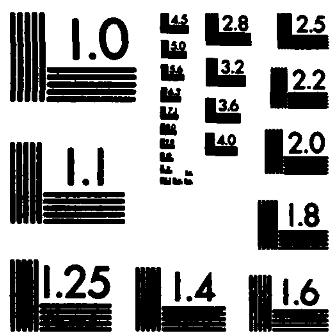

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telescopes on the basis of which must be determined the corresponding structural/design sizes/dimensions of telescopes and the angles between the axes of their rotation. System is calculated so that in entire its operating range actuator of telescopes would be operational, i.e., so that the mutual displacements of three telescopes and goniometric devices/equipment would occur without the mutual limitation.

3. A three-dimensional-crank scanning mechanism.

Operating principle. Let us examine the scanning device/equipment, in which the oscillatory motions of the scanning platform are realized with the aid of the three-dimensional/space crank gear (Fig. 75).

In this device/equipment in housing 1, rotated with the aid of the electric motor, is established/installed in crankshaft bearings 2, led to the rotation by means of gear 3, rolled on motionless gear 4. On flywheel crankpin 2 is arranged/located crank flywheel bushing 5, to which with the aid of the cylindrical articulation is connected connecting rod 6. The second connecting-rod end is established/installed in piston 7 and is connected with it with the aid of cylindrical ring. During the rotation of crankshaft connecting rod AB completes oscillatory motions. In this case scanning platform 8 realizes scanning field along the vibrational-rotational trajectory.

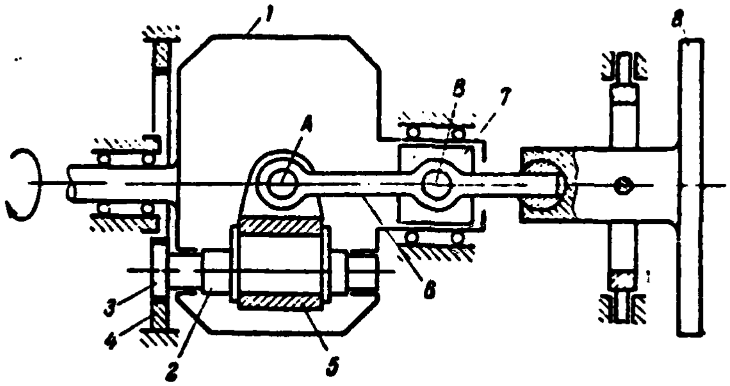

Fig. 75. Scanning device/equipment with the use of a three-dimensional-crank mechanism.

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Depending on the relationship/ratio of the sizes/dimensions of the crank throw, height/altitude of flywheel bushing and distance between centers of piston and axis of crankshaft, and also angle of the slope of the scanning platform relative to the axis of connecting rod, it is possible to perform any type of vibrational-rotational trajectory with any relationship/ratio C and R (see Fig. 1). It is necessary to note that in the device/equipment examined the connecting rod and the scanning platform with the oscillatory motion complete also rotation to certain angle. Because of this the form of the trajectory of scanning in this device/equipment differs somewhat from vibrational-rotational trajectories examined above. The scanning

platform is established/installed on the gimbal suspension and completes displacements relative to the central point of cardan mechanism. In this case the common rotary motion of actuator to the platform is not transmitted, since the corresponding rotation is realized in the elements of the hinged joint, which has three degrees of freedom. This hinge joint is established/installed on the connecting rod, which accomplishes three-dimensional/space displacements.

Research of kinematics and dynamics. The author investigated the kinematic and dynamic characteristics of this three-dimensional-mechanical conversion of rotary motion into the oscillatory[1].

FOOTNOTE [1]. G. P. Ktys. Investigation of kinematics and dynamics of a three-dimensional-crank mechanism. Collection of Works of MVTU. Department "Internal combustion engines". MVTU, 1955. ENDFOOTNOTE.

Are examined below basic kinematic and dynamic dependences of this scanning device/equipment.

As it was already noted, the device/equipment of the mechanism in question is reduced to the following. The single throw shaft, arranged/located in parallel to the axis of supporting cylinder, has

on the crankpin the flywheel bearing, to which with the aid of the cylindrical hinge joint is connected the connecting rod. To the second connecting-rod end is also with the aid of the cylindrical hinge joint connected the piston. The axis of cylinder and the axis of shaft lie/rest at one plane. During the rotation of crankshaft the piston moves not is only reciprocating, but also it completes recurrent-rotary motions around the axis to certain angle, in this case the connecting rod completes spatial motion and connecting rod big end describes complicated plane trajectory.

In this mechanism the axis of shaft and the axis of supporting cylinder must be parallel, otherwise it is necessary to establish/install the ball joint at one of the connecting-rod ends.

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With different relationships/ratios of parameters R, b and r (where R - crank throw, b - the distance between centers of cylinder and shaft, r - the distance between centers of flywheel neck and crank-pin) in the case of the parallelism of the axes of cylinders and axis of shaft this mechanism can have the following modifications:

1) with $b<R$ mechanism will not work on the kinematic reasons;

2) with b-R=r the piston of mechanism in one revolution of shaft completes one reciprocating course. The axis of connecting rod in the position of mechanism in v.m.t. coincides with the axis of cylinder. Connecting rod big end in this case describes the trajectory of drop-shaped form (Fig. 75);

3) with b-R>r the piston of mechanism in one revolution of shaft also accomplishes one reciprocating course, but in the position of the mechanism into v.m.t. the axis of connecting rod comprises with the axis of cylinder certain angle. The trajectory of connecting rod big end has a form of incorrect oval;

4) with b-R<r the piston of mechanism completes two reciprocating courses in one revolution of crankshaft; however, inertia piston thrusts on the wall of cylinder in this mechanism reach very high values, which makes impossible its use/application.

Because of this subsequently are investigated the kinematics and the dynamics only of mechanism with the relationship/ratio of parameters b-R=r.

Kinematics. During the analysis of the kinematics of this

mechanism were accepted the following designations (see Fig. 75).

R, α and ω - correspondingly the radius, angle of rotation and the angular velocity of crank; L=BC - length of connecting rod; b=OO' - distance between centers of cylinder and shaft; r=AC - distance between centers of flywheel neck and connecting rod big end; x=O'B - displacement of piston from point O'; ρ=O'C - projection of connecting rod on the plane, perpendicular to the axis of shaft; θ - angle of rotation of plane ρx, passing through axes ρ_1 and x and perpendicular to the axis of the wrist pin (this plane passes through the middle of wrist pin); S, v, j - path, speed and the acceleration of piston.

Let us examine the three-dimensional/space schematic of this mechanism, depicted on Fig. 76. The rotation of point A occurs in the plane of drawing; the axis of cylinder O'B is directed along the axis x.

Was selected the moving coordinate system τ_1, ρ_1, x, which accomplished oscillatory motions around x axis together with the plane of the fluctation of connecting rod.

From triangle OAA' we obtain:

$$\operatorname{tg}\theta=\frac{AA'}{A'O'}=\frac{R\sin\alpha}{b-R\cos\alpha}=\frac{\sin\alpha}{\lambda-\cos\alpha}$$

where λ=b/R

$$\frac{\sin\theta}{\cos\theta}=\frac{\sin\alpha}{\lambda-\cos\alpha};\quad \lambda\sin\theta=\sin\alpha\cos\theta+\sin\theta\cos\alpha;$$

$$\lambda\sin\theta=\sin(\alpha+\theta). \tag{1}$$

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After accepting

$$\alpha + \Theta = \psi,$$

we will obtain

$$\lambda \sin \Theta = \sin \psi.$$

Then in the polar coordinates ρ_1, Θ we determine the components of velocity of point A of component/link AC in the directions ρ_1 and r.

From triangle k'Ak we have:

$$\angle OAk = \alpha + \theta; \quad Ak' = R\omega;$$

$$Ak = \frac{d\varrho_1}{dt} = R\omega \cos[90 - (\alpha + \theta)] = R\omega \sin(\alpha + \theta) = R\omega\lambda \sin\theta; \ (2)$$

$$AA'' = \frac{d\theta}{dt} = \frac{R\omega}{\varrho_0} \cos(\alpha + \theta); \quad \angle A''Ak' = \alpha + \theta; \quad \varrho_0 = \varrho + r.$$

From triangle BO'C we determine

$$x^2 + \varrho^2 = L^2;$$

since

$$\angle BO'C = 90°.$$

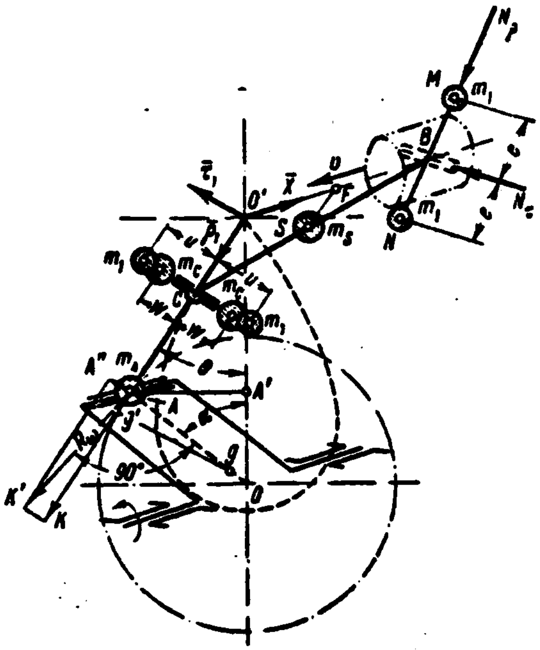

Fig. 76. Force conditions, moments/torques and equivalent masses in three-dimensional-crank scanning mechanism.

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Differentiating this expression two times, we determine speed and acceleration of the piston:

$$v = \frac{\rho}{x} \cdot \frac{d\rho}{dt}; \tag{4}$$

$$j = \frac{1}{x}\left[\left(\frac{dx}{dt}\right)^2 + \left(\frac{d\rho}{dt}\right)^2 + \rho\frac{d^2\rho}{dt^2}\right]. \tag{5}$$

Expression $d^2\rho/dt^2$, necessary in the calculations, can be obtained by direct differentiation of expression $d\rho/dt$, but in this

case is obtained sufficiently complicated expression; therefor. for the simpler determination of value $d^2\rho/dt^2$ let us examine triangle Ag'g, in which

$$\angle g'Ag = \alpha + \Theta.$$

The acceleration of point A is equal $R\omega^2$; and it is directed along a radius. Thus, from triangle Ag'g we determine the component of complete acceleration in the direction ρ

$$j_{\varrho} = R\,\omega^2 \cos(\alpha + \theta) \qquad (6)$$

and in the direction τ

$$j_{\tau} = R\,\omega^2 \sin(\alpha + \theta) \qquad (7)$$

The complete acceleration of point A in the polar coordinate system $\rho\Theta$ is expressed by the formula

$$j_A = \left[\frac{d^2\varrho}{dt^2} - \varrho_0\left(\frac{d\theta}{dt}\right)^2\right]\bar{\varrho} + \left[\varrho_0\frac{d^2\theta}{dt^2} + 2\frac{d\varrho}{dt}\cdot\frac{d\theta}{dt}\right]\bar{\tau}, \qquad (8)$$

since

$$\frac{d\varrho}{dt} = \frac{d\varrho_0}{dt}.$$

The first term of the right side of this formula is equal to the component of complete acceleration in the direction ρ, and the second - direction τ; therefore we equate them with respect to values J_{ϱ} and J_{τ}, obtained from formulas (6) and (7), and we determine values $d^2\rho/dt^2$ and $d^2\theta/dt^2$:

$$\frac{d^2\varrho}{dt^2} = R\omega^2\cos(\alpha + \theta) + \varrho_0\left(\frac{d\theta}{dt}\right)^2; \qquad (9)$$

$$\frac{d^2\theta}{dt^2} = -\frac{1}{\varrho_0}\left[R\omega^2\sin(\alpha + \theta) + 2\frac{d\varrho}{dt}\cdot\frac{d\theta}{dt}\right]. \qquad (10)$$

In Fig. 77 solid line depicted the curves, constructed according to the derived dependences. The curve of speed v of piston concerns the axis of abscissas at the point, which corresponds to v. m. T., and therefore the acceleration of piston in v. m. T. is equal to zero.

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In the case when in the case when difference b-R begins more than r, curve of speed v of piston (broken line) clear the axis of abscissas at the point, which corresponds to v. m. t. [upper dead center], but comprises with it certain angle, and therefore acceleration in v. m. t. has certain value. As is evident, the law of change S, v and j in this mechanism is in principle different from the law of a change of the parameters in flat-crank transmission.

In Fig. 78 it is evident that $Q_s = {}^1/_2Q$ and $x_s = {}^1/_2x$.

Differentiating this expression, we determine component/term of the complete acceleration of point S, which is the middle of the axis of the connecting rod (these values are necessary in further calculations):

$$\frac{d^2Q_S}{dt^2} = \frac{1}{2}\frac{d^2Q}{dt^2}; \qquad \frac{d^2x_S}{dt^2} = \frac{1}{2}\frac{d^2x}{dt^2}. \qquad (11)$$

Complete acceleration of point S in the cylindrical coordinate system

$$j_S = \left[\frac{d^2\varrho_S}{dt^2} - \varrho_S\left(\frac{d\theta}{dt}\right)^2\right]\bar{\varrho} + \left[\varrho_S\frac{d^2\theta}{dt^2} + 2\frac{d\varrho_S}{dt}\cdot\frac{d\theta}{dt}\right]\bar{\tau} + \frac{d^2z_S}{dt^2}\bar{i}. \quad (12)$$

After the substitution of formulas (11) in equation (12) we obtain

$$j_S = \frac{1}{2}\left[\frac{d^2\rho}{dt^2} - \rho\left(\frac{d\theta}{dt}\right)^2\right]\bar{\rho} + \frac{1}{2}\left[\rho\frac{d^2\theta}{dt^2} + 2\frac{d\rho}{dt}\cdot\frac{d\theta}{dt}\right]\tau + \frac{1}{2}\frac{d^2x}{dt^2}i.$$

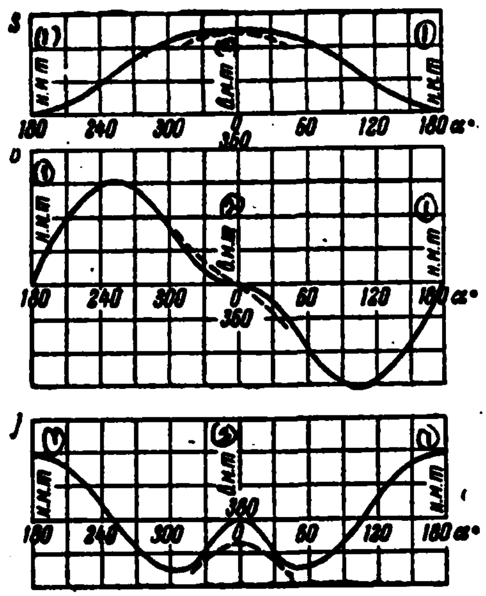

Fig. 77.

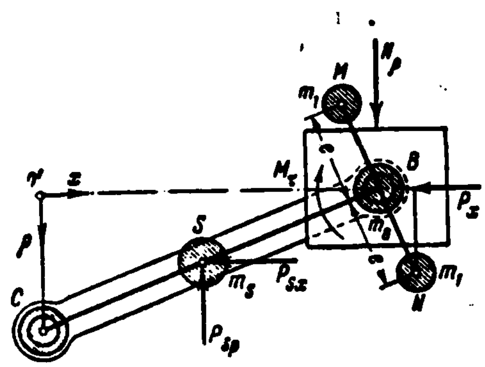

Fig. 78.

Fig. 77. Change in way of S, speed v and accelerating j sustaining piston of three-dimensional-crank scanning mechanism in dependence on α.

Key: (1). n. m. t. (2). V. m. t.

Fig. 78. Force conditions, moments/torques and equivalent masses in plane ρx of scanning mechanism.

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We determine the loan/borrowing of the acceleration of points M and N (see Fig. 77), arranged/located on the line, perpendicular to the axis of connecting rod, at the equal distances l from its cap/knob B.

The plane at which lie/rest points M and N, is perpendicular to the axes of fingers/pins.

From Fig. 77 we determine

$$x_N = x + \frac{l}{L}\varrho, \quad \varrho_n = \frac{l}{L}x.$$

Differentiating these expressions twice, we obtain:

$$\left.\begin{aligned} \frac{d^2\varrho_n}{dt^2} &= \frac{v}{L}\cdot\frac{d^2x}{dt^2}; \\ \frac{d^2x_n}{dt^2} &= \frac{d^2x}{dt^2} + \frac{v}{L}\cdot\frac{d^2\varrho}{dt^2} \end{aligned}\right\} \quad (13)$$

Substituting the obtained dependences into equation (12) for the complete acceleration of point in the cylindrical coordinate system we determine component/term of complete acceleration in the direction ρ- (j_{n_ϱ}) and in direction τ — (j_{n_τ}):

$$j_{n\varrho} = \left[\frac{d^2\varrho_n}{dt^2} - \varrho_n\left(\frac{d\theta}{dt}\right)^2\right] = \frac{v}{L}\left[\frac{d^2x}{dt^2} - x\left(\frac{d\theta}{dt}\right)^2\right]; \quad (14)$$

$$j_{n\tau} = \left[\varrho_n\frac{d^2\theta}{dt^2} + 2\frac{d\varrho_n}{dt}\cdot\frac{d\theta}{dt}\right] = \frac{v}{L}\left[x\frac{d^2\theta}{dt^2} + 2\frac{dx}{dt}\cdot\frac{d\theta}{dt}\right]. \quad (15)$$

Dynamics. In view of the smallness of the angular rate of rotation of housing around the axis of basic drive in comparison with

the angular velocity of crankshaft during the analysis of the dynamics of this system in the first approximation, the value of the speed of rotation of housing can be disregarded/neglected.

Let us determine the inertia forces, which act on the components/links of this scanning mechanism during its motion.

During the solution of the dynamics of mechanism were accepted the following designations (see Fig. 77, 78):

m - mass of connecting rod; m_s m_1 - diverse masses of connecting rod, located respectively in its center of gravity and on certain distance from caps/knobs B and C; e and u - coordinate of the diverse masses of connecting rod relative to caps/knobs B and C; J_x, J_y, J_z — moments of the inertia of connecting rod relative to principal axes; m' - mass of flywheel bearing; m_A and $2m'_C$ — diverse masses of flywheel bearing; f f' - distance of respectively reduced masses m_A and $2m_C$ relative to the center of gravity of flywheel bearing; ω - distance between the point of the application of mass m_C and the axis of the symmetry of bearing; J_s — can the inertia of flywheel bearing relative to the center of gravity.

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During the solution of the dynamics of this mechanism three-dimensional/space connecting rod was replaced by the dynamically equivalent system of the respectively coordinated masses, in this case the condition of the dynamic equivalency of connecting rod and given system was the equality of their kinetic energies.

The location of the reduced masses and their coordinates were selected, on the basis of the symmetrical form of connecting rod taking into account convenience in the solution of the three-dimensional/space dynamics of the connecting rod (see Fig. 77, 78).

Mass m_s was located in the center of gravity of connecting rod, two masses m_1 - at points M and N on the line, perpendicular to the axis of connecting rod and to the axis of finger/pin, on the equal distances l from the piston connecting-rod end. Other two masses m_1 were arranged/located on the axis of finger/pin at the equal distances also from connecting rod big end (see Fig. 77, point C).

For the symmetrical connecting rod during the selected location of the diverse masses and their coordinates in the final form were accepted the following conditions of reduction:

$$\left.\begin{aligned} m_s + 4m_1 &= m; \\ m_1L^2 + 2m_1l^2 &= J_x; \\ m_1L^2 + 2m_1u^2 &= J_y; \\ 4m_1l^2 + 2m_1u^2 &= J_z. \end{aligned}\right\} \qquad (16)$$

From these equations were determined the reduced masses and their coordinates:

$$m_1 = \frac{J_x + J_y - J_z}{2L^2}; \quad u^2 = \frac{J_z + J_y - J_x}{4m_1}; \quad l^2 = \frac{J_z + J_x - J_y}{4m_1},$$

$$m_8 = m - 4m_1.$$

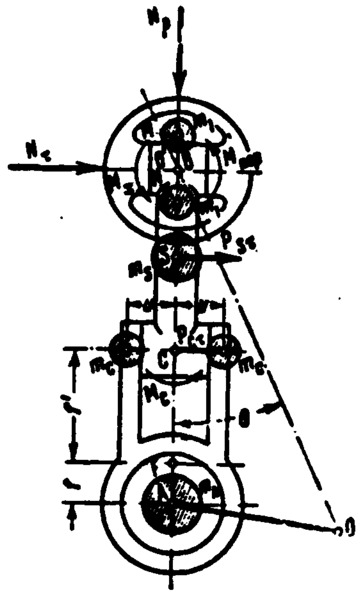

Fig. 79. Force conditions, moments/torques and equivalent masses in plane e_{a} of the scanning mechanism.

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During the calculation the flywheel bearing, which accomplishes plane motion, was replaced on the basis of equivalence of kinetic energies by the system of the respectively coordinated masses, arranged/located as follows (Fig. 79). Mass m_A was placed on the axis of flywheel neck, and two masses m_C — on the axis of crank-pin, in this case each mass m_C was arranged/located at a distance ω from the plane of the symmetry of flywheel bearing.

The conditions for bringing in the final form were following:

$$\left.\begin{array}{l} m_A + 2m_C = m'; \\ m_A f = 2m_C f'; \\ m_A f^2 - 2m_C(f'^2 + \omega^2) = J_S \end{array}\right\} \quad (17)$$

Since assigned magnitudes f, f', m and J_S, then the selected system of the diverse masses will satisfy this system of equations only with the observance of inequality $2m_C f'^2 + m_A f^2 < J_S$. Otherwise two reduced masses m_C it is necessary to place nearer to the center of gravity, decreasing distance of f'.

From the system of equations (17) we determine the values, necessary in further calculations:

$$m_A = \frac{m}{1 + \frac{f}{f'}}; \quad 2m_C\omega^2 = I_S - m_A f^2 - 2m_C f'^2.$$

In order to determine the complete effort/force of the inertia effect of piston on the cylinder, we expand this effort for two component/term:

N_ϱ, located in the plane of the fluctation of connecting rod (plane ϱx).which is perpendicular to the axis of wrist pin and passes through its middle, and N_τ, directed perpendicularly to plane ρx.

During the calculation it was accepted that the piston and crank-pins do not complete rotary motions around their axes.

For determining component/term N_{ϱ} let us examine mechanism in the plane ρx (see Fig. 77).

For positive direction N_{ϱ} we accept direction from the axis of shaft to the periphery of mechanism.

After composing the sum of moments with respect to point C, we determine

$$N_{\varrho} = P_{s_x}\frac{\varrho}{x} + \frac{1}{2}P_{s_x}\frac{\varrho}{x} + P_{s_{\varrho}}\frac{l}{2} + M_{\tau},$$

where

$$P_{s_x} = -m_s\frac{d^2x}{dt^2}; \quad m_s = m_{\text{пор}} + m_{s_{\text{шат}}} + 2m_1;$$

$$P_{s_x} = -\frac{1}{2}\frac{d^2x}{dt^2}m_s \text{ [см.}^{(1)}\text{ формулу (11)];}$$

$$P_{s_{\varrho}} = -m_s\frac{1}{2}\left[\frac{d^2\varrho}{dt^2} - \varrho\left(\frac{d\theta}{dt}\right)^2\right] \text{ [см.}^{(1)}\text{ формулу (12)];}$$

Key: (1). see formula.

M_{τ}— inertial moment, which appears from the fluctation of two masses m_1 with the arm l in the plane ρx and the variable/alternating angular acceleration.

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The efforts/forces, which appear from the progressive/forward displacement of masses m_1, are taken into consideration in term m_s.

The accelerations of these masses can be decomposed in the direction ρ and in the direction x in accordance with formulas (13) and (14).

We determine the inertial moment

$$M_{\tau}=2m_1\frac{l}{L}\left[\frac{d^2x}{dt^2}-x\left(\frac{d\theta}{dt}\right)^2\right]\frac{l}{L}\varrho+2m_1\frac{l}{L}\frac{d^2\varrho}{dt^2}\frac{l}{L}x=$$
$$=-2m_1\frac{l^2}{L^2}\left\{\frac{d^2\varrho}{dt^2}x+\left[\frac{d^2x}{dt^2}-x\left(\frac{d\theta}{dt}\right)^2\right]\varrho\right\}. \qquad (18)$$

The calculation of mechanism showed that value M_{τ} can be disregarded/neglected in view of its smallness.

After the substitutions of the given above expressions to Lu's form (18) in the final form we obtain:

$$N_{\varrho}=\left[m_B+\frac{1}{4}m_B\right]\frac{d^2x}{dt^2}\cdot\frac{\varrho}{x}+\frac{m_B}{4}\left[\frac{d^2\varrho}{dt^2}-\varrho\left(\frac{d\theta}{dt}\right)^2\right]. \quad (19)$$

Let us determine the effort/force, which acts on the wall of supporting cylinder in the plane $\tau\rho$ along the axis of the piston finger/pin (see Fig. 78). For the positive we accept effort/force N_{τ}, directed in the direction of the rotation of crank.

Let us exert to component/link BC all efforts/forces, which act in the plane $\tau\rho$, and, after composing the sum of moments relative to point A, let us determine

$$N_{\tau}=\frac{1}{\varrho_0}\left\{M_K+M_C-P_{C_{\tau}}r-P_{B_{\tau}}\left(r+\frac{\varrho}{2}\right)+M_s\right\}, \quad (20)$$

where

$$P_{C_\tau} = -m'_C\left[\varrho\frac{d^2\theta}{dt^2} + 2\frac{d\varrho}{d\theta}\cdot\frac{d\theta}{dt}\right] \text{ [см. формулу (8)]};$$

(1)

$$m'_C = 2m_{C_1} + 2m_1 + m_{C_{max}};$$

$$P_{B_\tau} = -m_B\frac{1}{2}\left[\rho\frac{d^2\theta}{dt^2} + 2\frac{d\rho}{dt}\cdot\frac{d\theta}{dt}\right] \text{ [см. формулу (12)]};$$

(1)

Key: (1). see formula.

M_x— moment/torque from the fluctation of masses m_1 with the variable/alternating arm and a varying acceleration of $d^2\theta/dt^2$.

We determine the variable/alternating arm q of the given moment/torque

$$q = \frac{l}{L}x.$$

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The component of the complete acceleration of point N in the direction τ is expressed by formula (15). In the final form the expression for moment/torque M_x takes the form

$$M_x = -2m_1x\left(\frac{l}{L}\right)^2\left[x\frac{d^2\theta}{dt^2} + 2\frac{dx}{dt}\cdot\frac{d\theta}{dt}\right].$$

In view of the fact that this moment/torque has insignificantly changing arm, it can be replaced by the moment/torque, which has the constant arm, equal to the average value of a change in the arm of real moment/torque. This considerably simplifies calculation formula

and it at the same time gives small error as a result of the low value of moment/torque M_x.

Thus,

$$M_x = -2m_1 a^2_{\text{cp}} \frac{d^2\theta}{dt^2}.$$

We determine total moment of the inertia

$$J_{\text{сум}} = J_{\text{пор}} + J_{B\,\text{вал}} + J_{C\,\text{вал}} + 2m_C\omega^2 + 2m_1u^2 + 2m_1a^2_{\text{cp}};\quad (21)$$

$$m_{C\,\text{сум}} = 2m_C + 2m_1 + m_{C\,\text{вал}} + \frac{m_s}{2}.$$

After substitution we obtain

$$N_\tau = \frac{1}{\varrho_0}\left\{J_{\text{сум}}\frac{d^2\theta}{dt^2} - m_{C\,\text{сум}}\left[\rho\frac{d^2\theta}{dt^2} + 2\frac{d\varrho}{dt}\cdot\frac{d\theta}{dt}\right]\tau - \right.$$

$$\left. - \frac{m_s}{4}\left[\varrho\frac{d^2\theta}{dt^2} + 2\frac{d\varrho}{dt}\cdot\frac{d\theta}{dt}\right]\varrho\right\}. \quad (22)$$

The calculation of mechanism showed that the latter/last term of this expression due to the smallness can be disregarded/neglected. In this case calculation formula will take the form

$$N_\tau = \frac{J_{\text{сум}}\frac{d^2\theta}{dt^2}}{\varrho_0} - m_{C\,\text{сум}}\frac{r}{\varrho_0}\left[\varrho\frac{d^2\theta}{dt^2} + 2\frac{d\varrho}{dt}\cdot\frac{d\theta}{dt}\right]$$

Thus, the lateral force, which acts on supporting/reference piston of this mechanism, has, in contrast to flat-crank transmission, variable/alternating angular direction.

Let us determine variable/alternating inertial moments, which must be applied to the shaft of this mechanism for imparting to it the uniform rotation in the case of neglect of frictional forces.

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Initial equation for determining the inertial moment is the expression

$$\frac{dT}{dt} = N = M_j \frac{d\delta}{dt}, \quad (23)$$

where N - power; T - kinetic energy; dδ/dt - angular velocity of this component/link.

We separately determine the energy, required for moving the components/links in plane ρx and for the motion in the plane $\tau\rho$; the obtained expressions we summarize. After differentiation we obtain expression dT/dt=N, whence we determine moment/torque M_j.

With the examination of motion in both planes mass m_A we do not consider, since it rotates evenly in by constant/invariable kinetic energy. The energy, required for the rotary motions of two masses m_1, in view of its smallness we do not consider.

We determine the value of kinetic energy, necessary for moving motion rods in plane ρ_x (see Fig. 78):

$$T = m_C\left(\frac{d\varrho}{dt}\right)^2 + \frac{m_s}{4}\left(\frac{d\varrho}{dt}\right)^2 + \frac{m_s}{4}\left(\frac{dx}{dt}\right)^2 + \frac{m_B}{2}\left(\frac{dx}{dt}\right)^2. \quad (24)$$

Differentiating the preceding/previous expression, we obtain

$$\frac{dT}{dt}=\left(m_s+\frac{m_s}{2}\right)\frac{d^2\rho}{dt^2}\cdot\frac{d\rho}{dt}+\left(m_B+\frac{m_s}{2}\right)\frac{d^2x}{dt^2}\cdot\frac{dx}{dt}.$$

In the plane $\tau\rho$ (see Fig. 78) was determined expression $dT/dt=M_j\,d\theta/dt$, the inertial moment for this plane, equal to the sum of all moments with respect to point B. Moment/torque M'_j oscillates this system with an angular velocity of $d\theta/dt$:

$$M'_j=M_N+M_x+M_C+P_{C_\tau}\rho+P_{B_\tau}\frac{\rho}{2}.$$

Producing the appropriate substitutions from formulas (8) and (12) and generalizing terms, we obtain

$$M_j'=J'_{\text{сум}}\frac{d^2\theta}{dt^2}+m_{\text{сум}}\left(\rho\frac{d^2\theta}{dt^2}+2\frac{d\rho}{dt}\right)\rho,$$

where

$$J'_{\text{сум}}=J_N+J_{B_{\text{пал}}}+J_{C_{\text{пал}}}+2m_{C1}\omega^2+2m_1u^2+2m_1a^2_{\text{ср}};$$
$$m_{\text{сум}}=2m_C+2m_1+m_{C_{\text{пал}}}+\frac{m_s}{4}.$$

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Substituting the value M'_j into formula (23), we obtain

$$\frac{dT}{dt}=\frac{d\theta}{dt}\left[J'_{\text{сум}}\frac{d^2\theta}{dt^2}+m_{\text{сум}}\left(\rho\frac{d^2\theta}{dt^2}+2\frac{d\rho}{dt}\right)\rho\right].$$

Then we obtain the complete inertial moment

$$M'_j=\frac{1}{\omega}\left\{\left(m'_C+\frac{m_s}{2}\right)\frac{d^2\rho}{dt^2}\cdot\frac{d\rho}{dt}+\left(m_B+\frac{m_s}{2}\right)\frac{d^2x}{dt^2}\cdot\frac{dx}{dt}+\right.$$
$$\left.+\frac{d\theta}{dt}\left[J'_{\text{сум}}\frac{d^2\theta}{dt^2}+m_{\text{сум}}\left(\rho\frac{d^2\theta}{dt^2}+2\frac{d\rho}{dt}\right)\rho\right]\right\}.$$

If the mechanism examined is performed with the crankshaft, which has one supporting/reference neck, then it is possible size/dimension AB to perform less than the diameter of flywheel crankpin. In this case is possible the creation of the very compact scanning device/equipment. It is necessary to note that in this mechanism with the decrease of distance of AB between the axis of flywheel crankpin and the axis of flywheel finger/pin occurs the approximation/approach of the form of trajectory to the rotational-rotational (see Fig. 1). In this case the trajectory of the center of the flywheel pin of connecting rod, and also trajectory of the axis of the guide approach the circle/circumference. In the case of AB, equal to zero, the trajectory of drive pin has a form of circle/circumference. With an increase in this distance occurs the approximation/approach of the form of trajectory to the vibrational-rotational (see Fig. 1). However, in the case when distance AB is equal to zero, mechanism becomes inefficient (for restoring its efficiency it is necessary at point B to place the ball joint). Therefore to fulfill size/dimension AB small is not recommended.

Experimental investigation.

The derived dynamic dependences were experimentally checked on the dynamic model of this mechanism, which was made with sizes/dimensions of b=109, R=47, r=62, L=190, S=25. On rod journal of single throw shaft was arranged/located one flywheel bearing with the connecting rod connected to it whose piston was moved in the supporting cylinder. For measuring the pressure of moving piston on the cylinder was prepared the measuring device, adjusted on this cylinder. On the supporting cylinder at angle of 120° one to another were arranged/located three special measuring plates, on which was moved the piston. Plates were connected with the aid of the adjusting screws with the figure lever, which transmits pressure on the piezoelectric quartz crystal sensor, signal from which after amplification was supplied to the loop oscillograph. Special lever/crank device/equipment independent of the place of the application of effort/force to the plate transferred it to the sensor without the distortions.

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During the experiment the sensors were placed into three measuring devices. The control of plates was conducted in such a way that with the slow displacement of the sustaining piston sensors would not show

pressure on the plates. This testified about the correctness of the geometric form of the cylinder, formed by three plates. After this were removed/taken the oscillograms of inertia forces.

On the derived dynamic dependences for the model in question were counted lateral forces N_{τ} and $\bar{N}_{\varphi}$ on the sustaining piston. These efforts were converted for three measuring plates and obtained effort/force N_{I}, N_{II}, N_{III} (solid lines in Fig. 80).

The oscillograms of efforts/forces, taken on the model (broken lines in Fig. 80), they showed a sufficient coincidence with the theoretical dependences and, therefore, they confirmed the correctness of the developed method of calculation of this scanning mechanism.

On the basis of the results of the studies of three-dimensional-yoke scanning mechanism in IAT by the author with the group of colleagues [1] is developed the version of the scanning device/equipment, represented in Fig. 81.

FOOTNOTE [1]. In the development of this device/equipment they participated by I. K. Mel'nichenko and O. I. Karyagin. ENDFOOTNOTE.

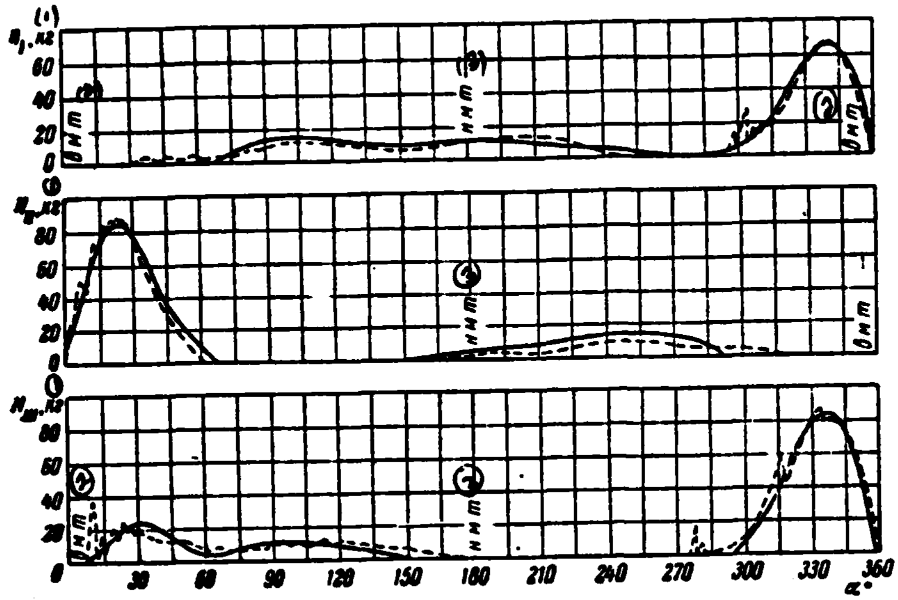

Fig. 80. Laws governing the change in the experimental (dotted lines) and determined by the calculated path (solid lines) of values lateral forces on the support piston of the scanning mechanism.

Key: (1). kg. (2). v. m. t. (3). n. m. t. [bottom dead center].

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This device/equipment differs somewhat from the device/equipment whose schematic diagram is depicted on Fig. 75. Basic differences are reduced to the following. The sustaining piston does not complete forward motions along the axis of supporting cylinder, and the necessary longitudinal travel along the crankshaft completes flywheel

bushing. The immobility of the center of the sustaining piston which in this mechanism completes only rotary motion, are created the spherical displacements of the scanning platform. This makes it possible to use the same method of the retention of the scanning platform from the rotation which was used in the previously device/equipment examined (see Fig. 68). In this case the retention of the scanning platform from the rotation is realized by the cylindrical hinge joint, which has two telescopic articulation (Fig. 82). The principle of action of this scanning device/equipment and detail of its design concept are examined earlier (see page 108).

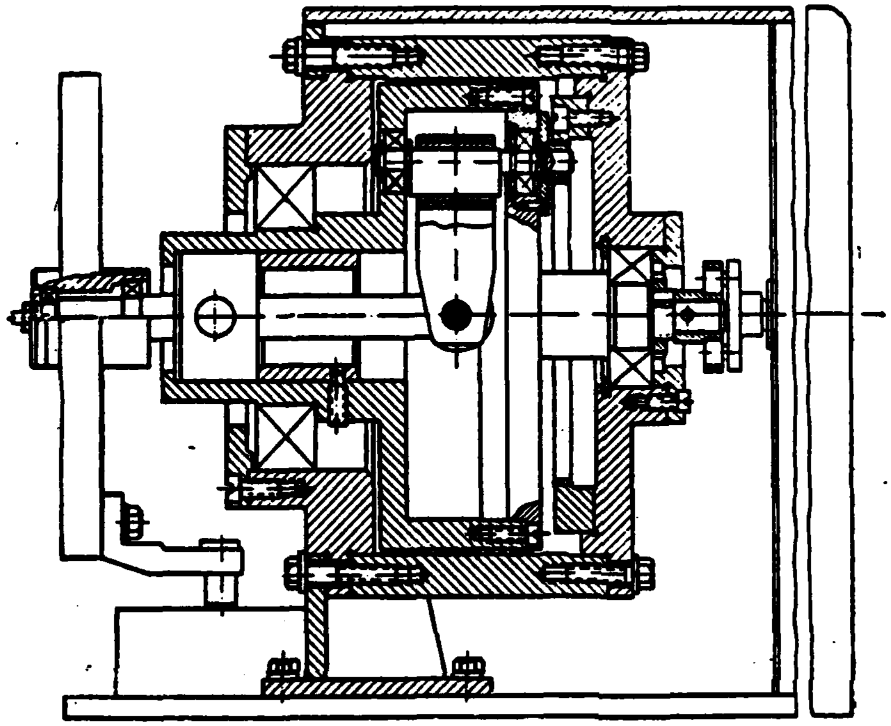

Fig. 81. Scanning device/equipment with three-dimensional-crank mechanism.

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The socket vibrational-rotational trajectory formed/shaped with the aid of this device/equipment is composed of two complicated component/term motions. Therefore for reconstruction of image of field on the synthesizing block/module/unit it is necessary to utilize the signals, formed/shaped in four sensors, connected with the scanning platform. These sensors through the amplifiers are

connected with two deflection coils of the cathode-ray tube of the block/module/unit, which reproduces the image (see Fig. 70).

The developed scanning device/equipment has the following characteristics: is realized scanning along the trajectory whose form is close to the socket vibrational-rotational trajectory with the relationship/ratio of parameters C=R (see Fig. 1). In this case a number of lobes/lugs of socket trajectory is equal to 10 and full wave of scanning is 80 s. On the scanning platform of device/equipment can be established/installed different receiving systems, including radiation, brightness and color pyrometers.

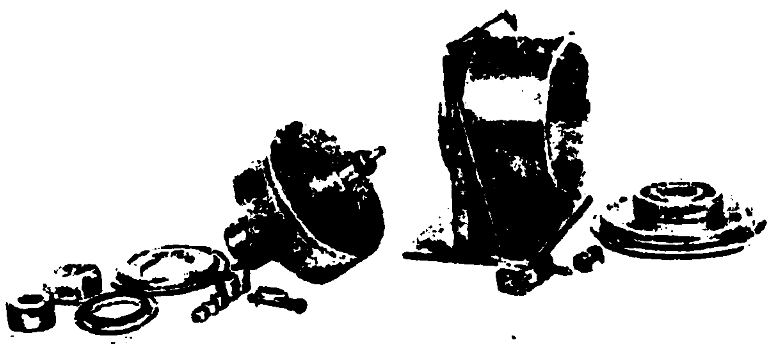

Fig. 82. The general view of the scanning node/unit of mechanism, represented in Fig. 81.

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